THE ROYAL AERONAUTICAL SOCIETY WAS FOUNDED IN 1866

JUNE, 1944
No. 402
Vol. XLVIII.

MONTHLY
PRICE
5/-

The Journal of The Royal Aeronautical Society

With which is incorporated The Institution of Aeronautical Engineers

Edited for the Council by Capt. J. LAURENCE PRITCHARD, Hon. Fellow

CONTENTS FOR JUNE, 1944

Monthly Notices

Structural Features of German Aircraft - *Leggett & Davison*

Correspondence

Reviews

Abstracts from the Scientific and Technical Press

Titles and References of Articles and Papers

The ROYAL AERONAUTICAL SOCIETY, 4, Hamilton Place, W.1

Telephones Grosvenor 3515 (3 lines)

Reliable books

THE FLIGHT TESTING OF PRODUCTION AIRCRAFT

By J. A. CROSBY WARREN, M.A. (Cantab.). A.F.R.Ae.S. With a Foreword by the Rt. Hon. Harold Balfour. An authoritative manual for test pilots, maintenance unit pilots, and squadron pilots of the R.A.F., ferry and airline pilots, private owners and all aeronautical and reference libraries. No other work on the flight testing of aircraft is available.

8s. 6d. net.

FLIGHT AND AIRFRAMES FOR THE AIRCRAFT FITTER

By D. O. BISHOP, B.Sc. (Eng.), and P. A. BOSANQUET, B.Sc. In this work there are many original features, one of particular interest being the section on Hydraulics. The authors have described how an aircraft hydraulic system is built in such a way that those who wish to master the principles can do so without taking a lengthy theoretical course.

10s. 6d. net.

AIRFRAME CONSTRUCTION AND REPAIR

By JOHN T. HENSHAW, A.F.R.Ae.S. A book for workers in aircraft repair factories and R.A.F. Technicians, dealing with all the details of airframe construction, workshop processes and the repair of damaged airframes. Fully illustrated by about seventy drawings.

7s. 6d. net.

RAPID NAVIGATION TABLES

By W. MYERSCOUGH and W. HAMILTON. These tables have been devised so that not only are the calculations to be made by the navigator reduced to a minimum, but the book itself presents the very few tables to which he has to refer in their most easily accessible form. The Plotting Card which is supplied with the book greatly facilitates the laying off of the intercept.

10s. 6d. net.

THE TESTING OF AERO ENGINES

By R. A. BEAUMONT, A.F.R.Ae.S. A practical book for Ground Engineers and Aeronautical students. The chapters—General Requirements Dynamometers, Test House Instruments and Accessories, etc., are written in a manner particularly suitable for those not conversant with the subject.

7s. 6d. net.

PITMAN'S, PARKER ST., KINGSWAY

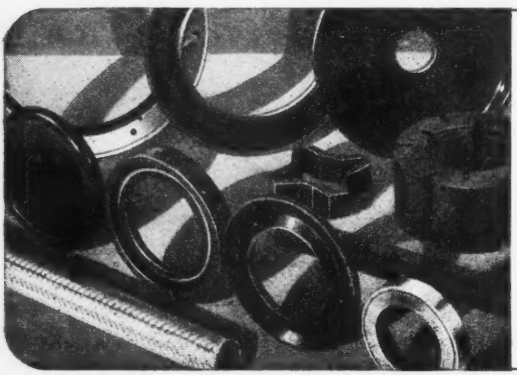
TREFOIL

BAKELITE PLASTICS

REGD. TRADE MARKS

Pioneers in the Plastics World

BAKELITE LIMITED, 18 GROSVENOR GARDENS, LONDON, S.W.1



HYDRAULIC PACKINGS SEALS • GASKETS

GACO is ideal for hydraulic sealing being grainless, resilient, non-porous, and highly resistant to oils, fuels and chemical corrosives. It is widely used in the hydraulic and pneumatic control systems of aircraft where only materials of the highest grade can be employed. Its unequalled surface finish and dimensional accuracy are well-known to all designers.

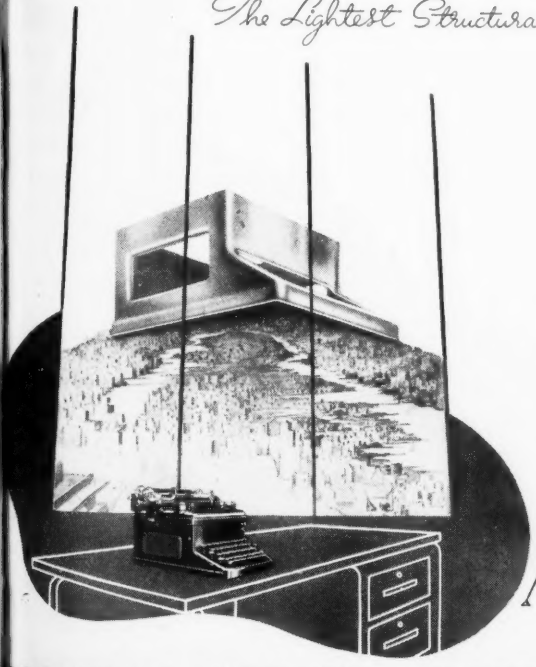
SYNTHETIC GACO RUBBER

GEORGE ANGUS & CO., LTD.
OIL SEAL WORKS, NEWCASTLE UPON TYNE

VICKERS-ARMSTRONGS LTD
Head Office: VICKERS HOUSE · BROADWAY · LONDON · S·W·1

VICKERS "WARWICK" TRANSPORT

The Lightest Structural Metal



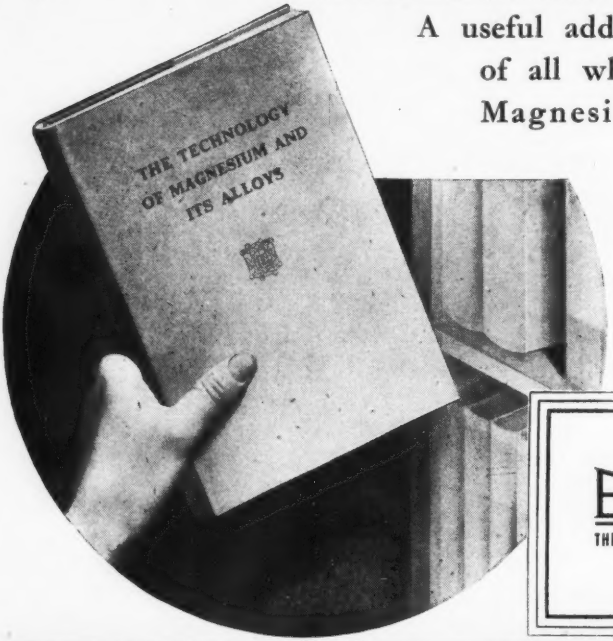
THE LIGHTEST FRAMES FOR TYPEWRITERS

Typewriters, duplicators, sewing machines, suitcases and all the other items of domestic and office equipment classified as "portable," will become far lighter than ever before when designers can use MAGNUMINIUM base alloys. Magnuminium is four times lighter than steel, possesses high strength/weight ratio, is unsurpassed in machinability and can be fabricated by methods similar to those used on other metals. Full details on request to the Sales Department.

MAGNUMINIUM
MAGNESIUM BASE ALLOYS

MAGNESIUM CASTINGS & PRODUCTS LTD • SLOUGH

A useful addition to the library of all who are interested in Magnesium and its alloys



Price : U.K., 30/-
plus 7d. postage
Abroad, 30/-
plus 1/3 postage

Cheques to be made out to F. A. Hughes & Co., Ltd.

ELEKTRON
REGISTERED TRADE MARK
THE PIONEER MAGNESIUM ALLOYS

• *Sole Producers and Proprietors of the Trade Mark "Elektron"*: MAGNESIUM ELEKTRON LIMITED, Abbey House, London, N.W.1 • *Licensed Manufacturers:* Castings & Forgings: STERLING METALS LIMITED, Northey Road, Foleshill, Coventry • Castings: THE BIRMINGHAM ALUMINIUM CASTING (1903) COMPANY LIMITED, Bromford Works, Smethwick, Birmingham • J. STONE & COMPANY LIMITED, Deptford, London, S.E.14 • *Sheet, Extrusions, Forgings & Tubes*: JAMES BOOTH & CO. (1915) LIMITED, Argyle Street Works, Nechells, Birmingham, 7 • Sheet, Extrusions, Etc.: BIRMETALS LIMITED, Woodgate, Quinton, Birmingham • *Suppliers of Magnesium and "Elektron" Metal for the British Empire*: F. A. HUGHES & CO. LIMITED, Abbey House, Baker Street, London, N.W.1

This 5,000 ton Aircraft Press is the largest of the modern self-contained type ever to be built complete under one roof. A similar press is installed in one of the Airframe Factories in this country

HYDRAULIC PRESSES

specially designed for the rubber pad process of forming metal aircraft parts are manufactured in the following standard sizes:—

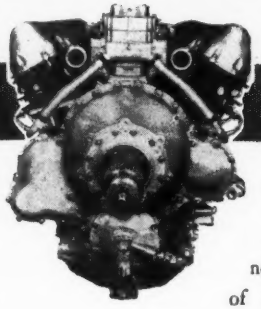
Tonnage	1000	2500	2500	5000
Pad Size	60" × 36"	96" × 48"	96" × 48"	168" × 50"
Max. No. of Loading Tables	2	2	4	4

H.P.M. FASTRAVERSE HYDRAULIC PRESSES

are also manufactured for numerous other applications

For particulars apply to Sole Agents and Engineering Representatives :—

A.C. Wickman LIMITED
• COVENTRY • ENGLAND •



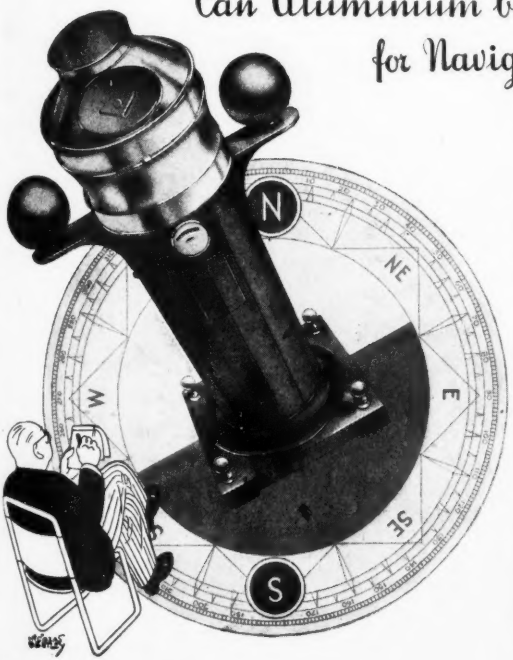
THE GRIFFON

For more than a generation, Rolls-Royce pre-eminence in Design and Craftsmanship has successfully met contemporary challenge. And now the Rolls-Royce Griffon . . . latest example of powered perfection . . . a worthy descendant of an illustrious line of aircraft engines . . . adding new lustre to a name which has long been an inspiration to engineering progress throughout the world.

ROLLS ROYCE

ROLLS-ROYCE AERO ENGINES — FOR SPEED AND RELIABILITY

Can Aluminium be used for Navigational Instruments?



YES—because aluminium and **HIDUMINIUM** aluminium alloys are virtually non-magnetic. This property is well known and the metal has been used for navigational instruments since the days of Lord Kelvin. Steel, which is normally used in ship construction, not only acquires permanent magnetism during building but is also continually affected by the earth's magnetic field and other magnetic disturbances. This leads to variable compass deviations—dangerous to the safe navigation of the ship. When after the war, HIDUMINIUM alloys are again available their use for structural purposes in ships will greatly reduce the danger from unstable deviations. Full information on the properties and characteristics of HIDUMINIUM alloys may be obtained from the Sales Department.

HIDUMINIUM ANTICORODAL

HIGH DUTY ALLOYS LIMITED SLOUGH

'Last night...! so much depended on —

Rotax Ltd.
London, N.W. 10

ROTAX MAGNETOS

The Manual of Technical Data on Flexatex gives useful technical data on Flexatex, together with full instructions on its applications and some remarks on its construction. Bona fide enquirers are invited to apply for the Manual. If details of fluids or gases to be conveyed are provided, specific information will also be supplied.

Photograph of section showing typical form of Flexatex construction
RESISTANT LINING
Extruded flexible tube of material selected to resist the high aromatic fuels or other liquids to be carried
TREATED FELT
A specially treated felt, bonded to the inner lining.
NON-METALLIC WIRE
Provides the flexing qualities of the finished hose. Light and tends to recover shape after pressure. Removes any necessity for electrical bonding.
OUTER COVERING
May vary according to requirements being either a layer of synthetic rubber or suitable plastic or a spirally wrapping of fabric treated with suitable material.
This photograph of one type of Flexatex hose graphically represents typical layers of Flexatex construction and omits the simplest

FLEXATEX

NON-RUBBER *flexible* **HOSE**

TYPES FOR A WIDE RANGE OF FLUIDS OR GASES

WILKINSON RUBBER LINATEX LTD., FRIMLEY RD., CAMBERLEY, SURREY. *Tel. Camberley 1575.* Also in Canada, Australia, South Africa, U.S.A., etc.

SIR W. G.
ARMSTRONG WHITWORTH
AIRCRAFT LIMITED
BRANCH OF HAWKER SIDDELEY AIRCRAFT Co. LTD.

Designers & Constructors of the Whitley Heavy Bomber

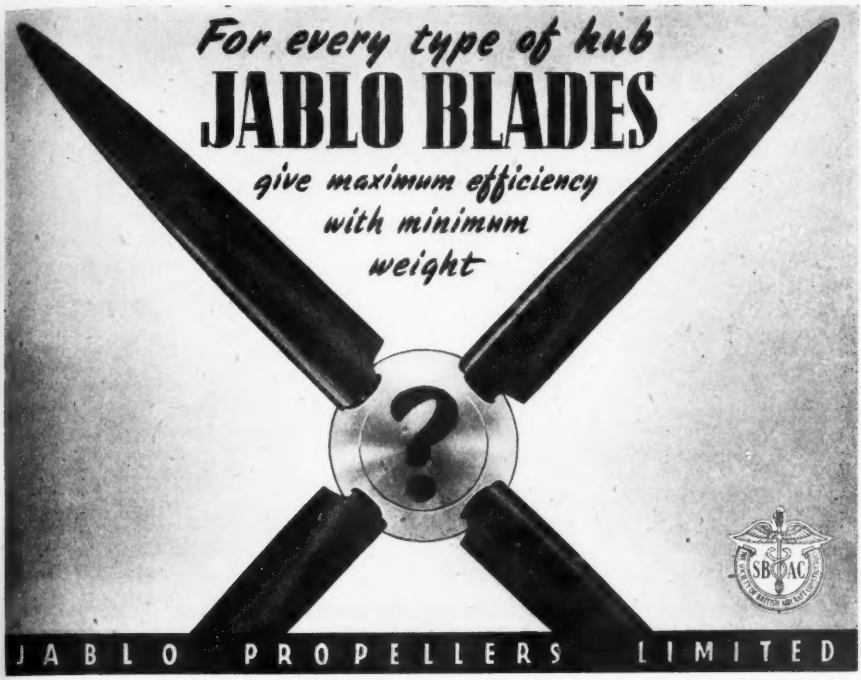
FIRTH-VICKERS
HEAT RESISTING
STEELS

FIRTH-VICKERS STAINLESS STEELS LTD SHEFFIELD

THE MEN ABOVE
depend on
THE MEN BELOW

Specialists in
JIGS & FIXTURES
PRESS TOOLS
AIRCRAFT
ASSEMBLY JIGS &
REFERENCE GAUGES
HEAT TREATMENT
SMALL ASSEMBLY
HAND TOOLS
FULLY A+D APPROVED

Leytonstone
JIG & TOOL Co LTD
606 HIGH ROAD, LEYTON, LONDON, E.10



'TAIN'T NATURAL'

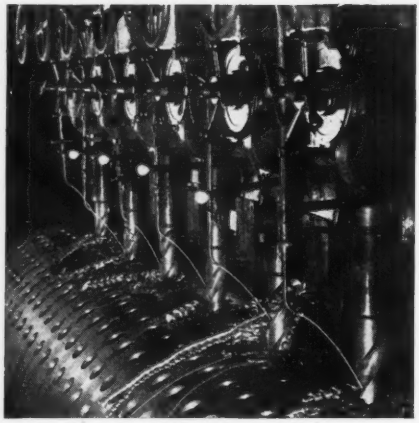
Those who plan the Air Services of the future should take note of this gentleman. There are still millions like him. A 'plane to them is a 'chancey' thing. Speedy? Yes. Exciting? Yes. Safe? No, not by long chalks. What will change their attitude? Not faster 'planes, or longer flights or even 'planes, with cocktail bars. They will accept flying as natural when a 'plane journey is as certain, as regular, as 'safe' as a train journey.

FIELD AIRCRAFT SERVICE

A Company of the HUNTING Group • FIELD CONSOLIDATED AIRCRAFT SERVICES LIMITED
LONDON OFFICE: BYRON HOUSE, ST. JAMES'S STREET, S.W.1

C.R.C. 2

FIRTH-BROWN

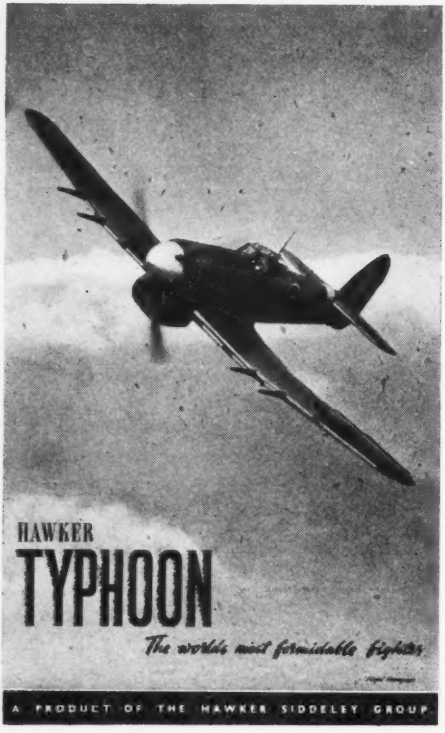


36,000 HOLES (NOT OUT)

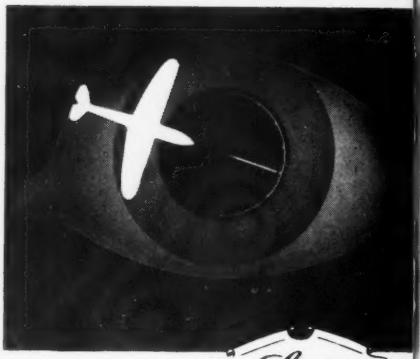
The set of 6 Drills shown above has been in use since 1938.

Working on Carbon Steel Boiler Drum Material, 28 to 36 tons/square inch, 3" thick, each Drill has already drilled 6,000 holes 3" diameter.

THOS FIRTH & JOHN BROWN LTD SHEFFIELD



INSTRUMENTS



Short & Mason Ltd.

Instruments for Aircraft by Short & Mason Ltd., London, E.17, makers of scientific instruments for more than seventy years

Everything depends on Accuracy

SMITH'S
AIRCRAFT INSTRUMENTS

WARWICK AVIATION CO. LTD.

AERONAUTICAL ENGINEERS
AND CONSTRUCTORS
Contractors to the Air Ministry, War Office and Admiralty
DESIGNERS OF AIRCRAFT

OFFICE : SALTISFORD, WARWICK
'Phone : Warwick 693

HIS VICTORIES MAY DEPEND ON THESE PARTS . . .

As the pilots of Britain will testify, the men who service their planes on the ground perform a duty which contributes in large measure to success in the air. To the fitters go great credit for their conscientious care in maintaining the planes at fighting efficiency. They in their turn testify to the importance of the efficiency of each component.

The various products made by Ferodo Limited for a wide number of applications in the building of aircraft, such as clutch discs, brake linings, bushes and washers, are made to those exacting limits, of that high quality and with the special characteristics that are demanded by this industry.

Why not consult the Technical Staff of Ferodo Limited if you require materials of this nature? No obligations will be entailed.

FERODO

PRODUCTS FOR AIRCRAFT CONSTRUCTION

FERODO LIMITED, CHAPEL-EN-LE-FRITH

REGD. TRADE MARK FERODO

ESC

Carbon & Alloy Steels

of the highest quality

FORGINGS, CASTINGS

DROP FORGINGS

RAILWAY MATERIALS

Small Tools & Tool Steels

ENGLISH STEEL CORPORATION LTD

VICKERS WORKS - SHEFFIELD

MORRISONS

CROYDON

AIRCRAFT CONSTRUCTION

MAINTENANCE AND REPAIR

DOWTY

Undercarriage and Hydraulic Equipment

DOWTY EQUIPMENT LIMITED

'WIZARD WINGS' OLD CHAP!"

REYNOLDS

FRIEND on left not interested in "good show and all that" —rather thinking about chance remark he heard—something about Reynolds Light Alloy Products and something called M.A.P.

Doesn't care a hang about Pilot Officer Prune's Progress. Just thinking—thinking—deeply about the way Reynolds Aircraft Components are going to change the MAP for future students of Geography—by faster routes as a matter of routine.

Wise old bird and rather wizard, too!

TUBES · RODS · SECTIONS · SHEET & STRIP IN "HIDUMINIUM" ALUMINIUM ALLOYS

REYNOLDS TUBE CO. LTD. & REYNOLDS ROLLING MILLS LTD., BIRMINGHAM, 11

We are the sole Concessionaires for the

Lear Avia
ACTUATING UNITS

As sole concessionaires in this country for LEAR AVIA Actuating Units, we invite Aircraft Designers and Engineers to attend

AN EXHIBITION AND WORKING DEMONSTRATION

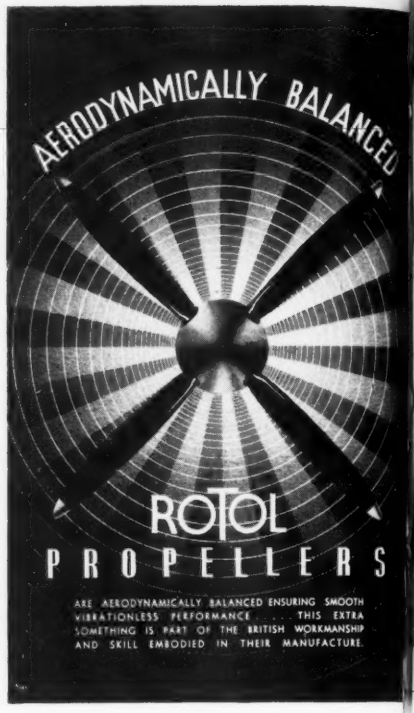
which is permanently set up at our London Offices,

62 BUCKINGHAM GATE, WESTMINSTER, S.W.1
(Victoria 1686-7)

You are invited to make an appointment so that we may explain at first hand the many uses and applications of these Actuators.

ULTRA ELECTRIC LTD.
(AIRCRAFT DIVISION)
WESTERN AVENUE, ACTON, W.3

Phone : Acorn 3434


AERODYNAMICALLY BALANCED
ROTOL
PROPELLERS
ARE AERODYNAMICALLY BALANCED ENSURING SMOOTH VIBRATIONLESS PERFORMANCE . . . THIS EXTRA SOMETHING IS PART OF THE BRITISH WORKMANSHIP AND SKILL EMBODIED IN THEIR MANUFACTURE.

BIRSO
TRADE MARK
NON-FERROUS CASTINGS and MACHINED PARTS for AIRCRAFT
Fully approved by Admiralty and A.I.D.
T. M. BIRKETT & Sons, Ltd
HANLEY - STAFFS
Telegrams: BIRKETT, HANLEY. Telephone: STOKE-ON-TRENT 2164

★ HOBSON INDUCTION PRESSURE (BOOST) CONTROLS

★ HOBSON-PENN AUTOMATIC MIXTURE CONTROLS

★ HOBSON PILOT'S COCKPIT CONTROLS

FOR ALL TYPES OF AERO ENGINES

HOBSON

(REGD. TRADE MARK)

Master Control Carburretters

H. M. HOBSON (AIRCRAFT & MOTOR) COMPONENTS LTD.

THE

WHIRLWIND

FIGHTER-BOMBER

★ ★ ★

Designed and Constructed by

WESTLAND AIRCRAFT LIMITED

ROUND THE CLOCK BOMBING

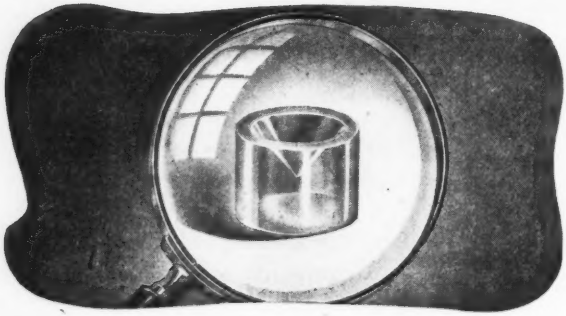
With unrivalled air crews, superb organisation and equipment without equal the Allied Air Forces are bombarding the enemy continuously night and day

LODGE

PLUGS

are playing a vital part in these operations "all round the clock."

LODGE PLUGS LTD., RUGBY.



"V" TYPE
SANWEST
INSTRUMENT BEARINGS

A Jewel Beyond Price

A Kingdom has been offered i
a horse . . . but even greater,
the time of emergency, was t
value of having available t
process for the production
"SANWEST" jewels wh
supplies of other instrum
bearings were cut off alm
overnight. The "SANWES
V Type bearings, which h
been produced since those
days, have given comp
satisfaction under the most ardu
conditions.

In 3 sizes ; 1, 1¼ *and* 2 *mm.*

SANGAMO WESTON LTD., ENFIELD, MIDDLES

THE JOURNAL
OF
THE ROYAL AERONAUTICAL SOCIETY

With which is Incorporated The Institution of Aeronautical Engineers.

CONTENTS FOR JUNE, 1944

	PAGE
MONTHLY NOTICES	163
STRUCTURAL FEATURES OF GERMAN AIRCRAFT, BY D. M. A. LEGGETT, Ph.D., A.F.R.Ae.S., and J. H. H. DAVISON, B.Sc.	167
CORRESPONDENCE	202
REVIEWS	202
ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS	379
TITLES AND REFERENCES OF ARTICLES AND PAPERS	394

THE JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY *was founded in* 1897 *in succession to the* ANNUAL REPORTS.

For the opinions expressed in Papers that are signed or initialled the authors alone are responsible. None of the papers or paragraphs must be taken as expressing the opinion of the Council of the Royal Aeronautical Society unless such is definitely stated to be the case.

The Journal is published monthly at the Offices of the Society, 4, Hamilton Place, Piccadilly, London, W.1.

Subscriptions per annum, £3 . 3 . 0 post free; Single Numbers 5/- or 5/3 post free.

All communications for publication in the Journal, or on general matters affecting the Society should be addressed to—

The Secretary and Editor,
J. Laurence Pritchard,
4, Hamilton Place, W.1.

The Society's Bankers are Messrs. Coutts & Co.

All communications respecting Advertisement matters should be addressed to—
The Advertisement Manager, Journal of the Royal Aeronautical Society,
4, Hamilton Place, W.1.

Telephone: Grosvenor 3515-3516-3517. Telegraphic Address: "Didaskolas, Audley, London."
Or to— T. G. Scott & Son, Ltd., Talbot House, Arundel House, London, W.C.2.
Telephone: Temple Bar 1942/3.

YES
Telephones—Armley
38234 & 38291 2 lines

Y. E. S. LTD.

YES
Telegraphic Address—
"YES, LEEDS"

PHOSPHOR BRONZE AND GUNMETAL BEARINGS & BUSHES

OF THE HIGHEST QUALITY . . . . CAST BY THE
"EATONIA" (WATER-COOLED) PROCESS

CASTINGS AND BARS AND FINISHED MACHINED PARTS SUPPLIED TO THE LEADING
AEROPLANE ENGINE MAKERS MOTOR VEHICLE ENGINE MANUFACTURERS
MARINE ENGINE BUILDERS

Contractors to all Government Departments

YORKSHIRE ENGINEERING SUPPLIES LIMITED
BRONZE FOUNDRIES, WORTLEY, LEEDS, 12

Aircraft Engineering

FOUNDED 1929

The Monthly Technical and Scientific Organ of the Aeronautical Engineering Profession
Edited by Lt.-Col. W. Lockwood Marsh, O.B.E., F.R.Ae.S., M.S.A.E., F.I.Ae.S.

Single Copies **2s. 3d.** post free. Ordinary Subscription : **26s. 0d.** per annum, post free
SPECIAL SUBSCRIPTION RATE *For Students, Associates and Graduates of the Society* : **21s. 0d.** per annum, post free

PRINCIPAL JUNE CONTENTS :

The I.Ae.S. Annual Meeting. A. Klemin
Determining Intermittent Ratings. H. Rissik.
Automatic Power-Unit Controls J. Lowrey.
The Acetylene Thermoplastics. G. Fitzgerald-Lee.
Moulded Plywood in Aircraft Construction. R. D. Hiscocks.
Plastics in Engineering. W. Gallay.

BUNHILL PUBLICATIONS LIMITED, 12 Bloomsbury Square, London, W.C.1

Since 1916

CERTUS COLD GLUE

has played a vitally important part in the construction of wooden aircraft components. The test of time has conclusively proved its extraordinary durability and unfailing strength under the most drastic conditions. For this reason the leading Aircraft Manufacturers specify "Certus."

Approved to B.S.S. 3.V.2.

● The practical co-operation of our experienced Technical Staff is available at all times

CERTUS

Regd. Trade Mark

Phones: HOP 1297 HOP 1558

Sole Manufacturers:

CENTRAL CHEMICALS LIMITED

ADHESIVE SPECIALISTS

CENTRAL BUILDINGS, 24 SOUTHWARK STREET, LONDON, S.E.1

Grams: Entramica, Boroh, London

(Fully approved for Testing and Issue of Release Notes under Air Ministry Ref. 437610, July, 1923)

A. V. ROE & CO., LIMITED

Branch of Hawker Siddeley Aircraft Co., Ltd.

Filters for Aircraft

● VOKES AIR FILTERS give 99.9% sustained efficiency of filtration, eliminating all particles down to the size of one micron with negligible resistance and effect upon rated altitude and speed. VOKES OIL FILTERS, both high and low pressure for Gun Turrets, Hydraulic Under carriages, Main Circuit Filtration, filter the whole of the delivered oil, removing all impurities down to .00004" dia., giving a sustained efficiency without any appreciable resistance to flow. Vokes Filters for Test-Bed equipment are in use by all the principle producers of aero-engines. Vokes Flame-trap Silencers extinguish all tell-tale flames and are applicable to radial engines and engines in line. It will pay you to consult the firm who specialise in filtration problems only.

High Pressure Oil Filter.

VOKES LTD FILTRATION EXPERTS LONDON · S.W.

DESIGNERS, PATENTEES AND MANUFACTURERS OF AIR, OIL AND FUEL FILTERS AND SILENCERS.

THE ROYAL AERONAUTICAL SOCIETY

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS.

MONTHLY NOTICES

JUNE, 1944.

Election of President.

Sir A. H. Roy Fedden, D.Sc., F.R.Ae.S., was elected President of the Society for the year 1944-1945 at the May meeting of Council and takes office on October 1st, 1944.

Election of Vice-Presidents.

Mr. W. C. Devereux, F.R.Ae.S., and Mr. R. K. Pierson, C.B.E., F.R.Ae.S., were elected Vice-Presidents of the Society for the year 1944-1945 at the May meeting of Council and take office on October 1st, 1944.

Associate Fellowship Examinations.

Entries for the December, 1944, Associate Fellowship Examinations must be received by the Secretary by September 30th, 1944.

Members will be interested to know that the Society has recently made arrangements for over thirty candidates to take the examination in Prisoner of War Camps.

Income Tax.

In response to numerous inquiries with regard to a rebate on Income Tax for their subscriptions, the following is a copy of a letter received from the Principal Inspector of Taxes:—

" Ref. H.R.S. 34/C.I. 4420/63.

Dear Sir,—Further to your interview with Mr. Stonely at this office on the 19th July, I am now in a position to inform you that the Board of Inland Revenue will not raise objection to the allowance as an expense for Income Tax purposes of annual subscriptions paid by members who are:—

(i) Assessable under Schedule D of the Income Tax Acts in respect of professional or trading profits, subject to the decision of the Commissioners who make the assessment that such subscriptions are sufficiently closely related to the business carried on; or

(ii) Assessable under Schedule E in those cases only in which continual membership of the Society is an essential condition of the terms of appointment.

Yours faithfully,

(Signed) GEO. WILCOCK,

Principal Inspector of Taxes."

Election of Members.

The following Members were recently elected:—

Associate Fellows.—William Alfred Bateman, Charles Douglas Carmichael, Gerard Mervyn Cutler, Alun Davies Edwards, Laurie Frederick Fox, John Leslie Hewitt (from Graduate), Robert James Rackham, Edgar Wilhelm Reissner (from Graduate), William Macey Widgery, Henry Scott Wilkinson, Henry Moir Wilson.

Associates.—Harry Edward Adams (from Student), Wilfred Adrain Bastable, George Blacklock, Anthony Quentin Cairns, Eric Leslie Carlisle, Edward Mark Champion, Thomas Guy Ebden Cockbain, William Samuel Cook, William Harry Edwards, james England, Cecil Arthur Forecast, John Thompson Goddard, John Samuel Griffiths, Stewart Douglas Hall (from Student), Aldred James Hallas, Walter Noel Hobbs, Ernest Stanley Hamilton, Herbert Jack Jauncey, John Arthur Jones, Norman Wilfred Jones, William Sydney Jones, John William Layfield, Charles Edmund Low, Edward Joseph Maher, Richard Middlebrough, Arthur Edward Morton, Charles Douglas Naylor, Guy Lancelot Newton-Wade, Thomas Dixon Nisbet (from Student), John James O'Hara, Leonard William Alexander Osborne, Claude Raymond Peter, Charles Stanley Radden, Harry Leo Ranson, Richard S. Randolph, Douglas Melville Read, George Murray Robertson, Stanley Herbert Sharp, Geoffrey Patrick La Trobe Shea-Simonds, Allan Marshall Sinclair, Albert George Strawford, Cyril Noel Sworder, Wilfred Charles Tompkins, Frederick James Varley, Hubert John Walters, John James West, James Wilson George William Wright.

Graduates.—Alan Farrer Barker (from Student), Leonard Herbert Barker, Thomas Campbell Beswick, Ian Hammond Blick, Alfred Denis Snowdon Carter, John Francis Dooley, Peter William Dryland (from Student), Albert Henry Figg, John Brodie Goodsir, Thomas Cotton Goodwin, Cecil Albert Harwood, Dennis John Higton, Mervyn Breeze Jones, Ronald William Milton Lee, Charles Clements Murphy, Harold James Payne, Peter Person (from Student), Dennis Martin Sealey, Douglas Melville Seath, Sydney Snell, Harold Peter Stapleford.

Students.—Robert Hastings Adams, John Ernest Allen, Denys Stanley Bliss, Reginald Arthur Bridgeman, Richard Peter Castle, Bryan Musgrave Collings, Peter Herbert Cook, Walter Henry Cox, Desmond Taylor Dawe, Sydney Montgomery Ellis, Derek Godfrey Travers Harvey, Raymond James Hill, Derek Charles Howe, Gordon Thomas Knight, Anthony Richard King, Llewellyn Marriott Lloyd, Donald Harrison Lord, Leonard McCadden, Robert Marshall Martin, James John Chalmers Reid, Derek Robert Samson, David William Scott, John Geoffrey Sherburn, Alan Douglas French Smith, Clarence Stewart, Peter John Vinson, Peter Vincent Webb, Ahmed Nasr El din Zamzam.

Companion.—Alexandre Siniak.

Birmingham Branch.

It has been suggested that a Branch of the Society be formed in Birmingham. Will those members in and around Birmingham who are interested write to the following member?—

A. G. Strawford, A.M.I.E.I., A.R.Ae.S.,
12, Cranmore Avenue, Handsworth, Birmingham 21.

Correction.

In the paper by Mr. E. J. Jones, on " Flight Testing Methods," published in the May (1944) Journal, reference was made by the author to the " Desyn " equipment. " Desyn " is the registered trade mark of Smith's Aircraft Instruments to signify their remote indicators.

Additions to the Library.

The following books have been added to the Library :—

Pamphlets in italics with location reference following in brackets.
Books marked * or ** may not be taken out on loan.

B.a.313.—*Curtiss (A-25) Helldiver. Curtiss-Wright Corporation. (Press release, Feb. 14, 1944. Stencil.)* (Y.3.ii.C.)

B.a.314.—*The Vickers Warwick Transport. Ministry of Aircraft Production. (Press release, March 30, 1944. Stencil.)* (Y.3.iii.28.)

C.d.150.—*L/A Notes. " Ensign." Randal Press, Erith.* 1944. (PC.1.c.7.)

D.b.204.—*Requirements of Local Air Transport Service. Edward Warner. Reprint from " Aeronautical Engineering Review," Feb.*, 1944. (Y.6.a.37.)

D.c.93.—*The Development and Forecasting of Airport Requirements. Edward Warner. Lecture before Boston Soc. of Civil Engineers, March 22*, 1944. *(Stencil.)* (Y.4.ii.a.32.)

D.d.20.—*Education and Training for Engineers. Institution of Electrical Engineers.* 1943. (PE.2.b.13.)

E.h.4.—Jig and Fixture Practice. H. C. Town. Paul Elek. 1944. 10/6.

*G.b.4.—*British Standards Institution: Aircraft Material Specifications.* 1944. 1/- each :—
5SP.4. Steel Pins.
6V.10. Liquid and Jelly Gelatine Glues.

G.e.A.94.—*Wrought Light Alloys Development Association: Information Bulletin* :—
No. 6. Resistance Welding of Wrought Aluminium Alloys. 1944. 1/-.

I.a.35.—Practical Analytic Geometry with Applications to Aircraft. Roy A. Liming. Macmillan Co., New York. 1944. $4.50.

*I.e.30.—Standard Four-Figure Mathematical Tables. (Edition A: Positive Characteristics.) L. M. Milne-Thompson and L. J. Comrie. Macmillan and Co. 1931. 10/6.

J.g.202.—Fogs, Clouds and Aviation. W. J. Humphreys. Baillière, Tindall and Cox. 1944. 16/6.

L.a.48.—*You Can Fly. Capt. D. M. K. Marendaz. Bernards, Ltd.* 1944. 2/-. (PL.1.a.8.)

L.d.202.—*Star Recognition. Joseph I. Fell. Sir Isaac Pitman.* 1944. 2/-. (PL.1.b.10.)

N.a.79.—*Planning of Science. Association of Scientific Workers.* 1944. 2/6. (PN.1.a.9.)

N.a.80.—Abstracts of Dissertations Approved for the Ph.D., M.Sc. and M.Litt. Degrees in the University of Cambridge (1942-1943). Cambridge Univ. Press. 1944.

Q.b.74.—Report of Proceedings of A.S.L.I.B. 18th Conference. 1943. 6/-.

**S.c.12.—How Our Army Grew Wings. Col. C. De Forest Chandler and Brig. Gen. F. P. Lahm. Ronald Press, New York. 1943. $3.75.

S.e.80.—Youth at War. (Omnibus volume, including: Fighter Pilot, by Paul Richey; Sub-Lieutenant, by Ludovic Kennedy; and Infantry Officer, by Anthony Irwin.) B. T. Batsford. 1944. 15/-.

T.a.112.—*Juan de la Cierva. (In Memoriam.) Harold F. Pitcairn. Privately printed. U.S.A.* 1939. (Y.5.C.)

*UG.7/5.—*Mitteilungen aus dem Institut für Aerodynamik, Zürich* :—

No. 8. Das Institut für Aerodynamik an der Eidgenössischen Hochschule. Dr. J. Ackeret. (1943.)

*UU.c.—*National Advisory Committee for Aeronautics, U.S.A.: Technical Memoranda* :—

No. 1,062. Investigation of Single Stage Axial Fans. P. Ruden. (From Luftfahrtforschung, July and Sept., 1937.)

*X.b.149.—Engineering Materials Annual, 1944. Ed. by H. H. Jackson. Paul Elek, Ltd. 8/6.

*X.b.150.—Engineering Production Annual, 1944. Ed. by H. H. Jackson. Paul Elek, Ltd. 8/6.

*X.c.Cz.2.—Army and Air Force Technical Dictionary: English-Czech, Czech-English. Czechoslovak Ministry. Evans Bros., Ltd. 1942. 6/-.

J. Laurence Pritchard, *Secretary and Editor.*

PROCEEDINGS.

A meeting of the Society was held at the Institution of Mechanical Engineers, Storey's Gate, London, S.W.1, on Thursday, February 24, 1944. Mr. A. Gouge, the President, was in the chair.

THE CHAIRMAN, in opening the meeting, said that Dr. Leggett and Mr. Davison were well qualified to give their paper on " Structural Features of German Aircraft " because they had had a good opportunity of seeing what the Germans were doing.

The following paper was then read:—

STRUCTURAL FEATURES OF GERMAN AIRCRAFT.

By D. M. A. LEGGETT, Ph.D., A.F.R.Ae.S., and J. H. H. DAVISON, B.Sc.

1. HISTORICAL INTRODUCTION.

2. FIGHTER DESIGN.
- 2.1. General description of Me. 109, 110, 210, 410, F.W. 190 and Hs. 129.
- 2.2. Wing design.
- 2.3. Fuselage design.
- 2.4. Tailplane design.
- 2.5. Miscellaneous design features.

3. BOMBER DESIGN.
- 3.1. Description of Do. 217.
- 3.2. Description of Ju. 88.

4. SPECIAL DESIGN FEATURES OF GERMAN AIRCRAFT.
- 4.1. Services.
- 4.2. Tanks.
- 4.3. Castings and welded components.
- 4.4. Engine mountings.
- 4.5. Materials.
- 4.6. Surface protection.
- 4.7. Spot welding.
- 4.8. Access doors and engine cowlings.
- 4.9. Provision for inspection and maintenance.

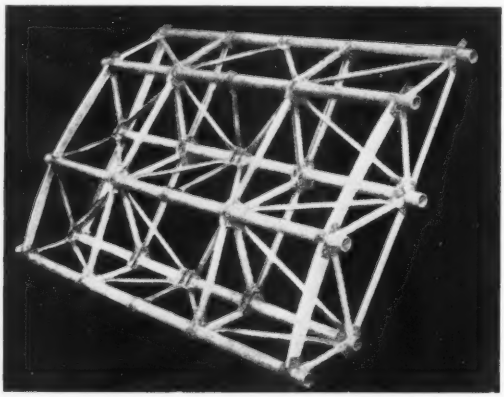
5. SOME GENERAL CONCLUSIONS.
- 5.1. Design efficiency.
- 5.2. Design from standpoint of production and maintenance.
- 5.3. Summary.

---

1. HISTORICAL INTRODUCTION.[1]

Although this paper is primarily concerned with the structure of current German military aircraft, no apology is needed in considering for a few moments some of the outstanding developments that took place 20 or 30 years ago.

In the early days of any branch of engineering, there are always a few individuals in each country who stand head and shoulders above their fellow workers in the same field, and aviation is no exception. But, whereas in this country quite a number of people spring to mind as having made exceptional contributions to aeronautics, in Germany one name stands out pre-eminent—that of Junkers. Hugo Junkers was born in 1859 and soon showed promise as a scientist and engineer. His technical training was varied, and at the age of 36 he founded at Dessau the engineering firm which bears his name. In 1910 he foresaw the possibility of an all-wing machine and took out a patent "For an aeroplane with hollow body for housing all members not contributing to the lift," and in 1913 he increased the scope of his activities by working on the development and production of engines. As a result, when the European war broke out in 1914, he had come to two very far-reaching conclusions. First, that due to its durability and uniformity, metal was preferable to wood as a basic material for aircraft construction; second, that because of the need for reducing parasite drag to a minimum the monoplane would replace the biplane.



[*Crown copyright reserved.*]

FIG. 1.

Wing framework of early Junkers machine.

Up to 1914 aviation was generally regarded as the field of the rash experimenter, but an appreciation of the part which it might play in warfare gave enormous impetus to all matters aeronautical, and with Junkers the result was the first successful all-metal monoplane. It was constructed of steel, contained a 100 h.p. engine, and in addition to being the first all-metal aeroplane, it was also the first machine with unbraced cantilever wings. It was, moreover, essentially of stressed skin design, as the wings were without spars, and all the direct stresses were taken by the skin. This was of sheet steel, 4/1000 in. thick, which was stabilised by a corrugated sheet of similar thickness on the inside. But although amply strong enough the machine was heavy, and its low rate of climb soon made desirable the development of a lighter construction. As the high weight was primarily due to the impossibility of exploiting the full strength of steel owing to the extreme thinness of the sections used, there was an obvious need for a less dense material, and the way was thus opened for the change from steel to duralumin.

Considerable development work had to be done first, however, and it was not until 1917 that Junkers produced the two first all-dural machines, a biplane,

so as to conform with army requirements, followed a few months later by a low wing monoplane. In both these machines the wing construction was similar and consisted of a corrugated skin covering which took the torsion, and a statically indeterminate framework which took the bending. The spars were tubes, and taper was obtained by telescoping the tubes at the joints (Fig. 1). Ribs, however, were few as the corrugated cover was deemed adequately stiff in bending to maintain a sufficiently exact aerofoil section. In the second machine mentioned, the monoplane, a further striking feature was the employment of a centre frame which served as a foundation for the whole structure and to which were attached the wings, fuselage, engine mountings, and undercarriage fittings. Considering the date at which it was built, more than 25 years ago, this machine embodied a remarkable number of present-day structural ideas, and it is significant that a machine of this type was in active use for at least ten years.

[*Crown copyright reserved.*]

FIG. 2.

Part of fuselage of early Junkers machine.

As from 1918 onwards progress in structural design ceased to be characterised by the violent changes of the war and pre-war years and was more in the nature of a gradual evolution, we shall pass over the intervening years, and proceed directly to a detailed examination of some of the more important present-day types.

2. FIGHTER DESIGN.

2.1. *General description of Me. 109, 110, 210, 410, F.W. 190 and Hs. 129.**

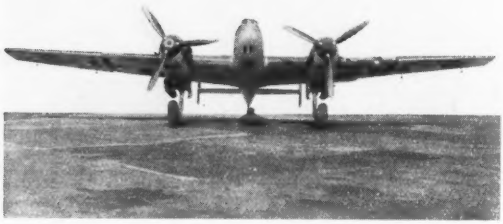
The Me. 109 is a low wing, single-seater, single engine monoplane, and with the exception of the flaps and control surfaces, which are usually of fabric, the

* Strictly, the HS.129 is a ground attack aeroplane rather than a fighter, but throughout this paper, in which there is no point in sub-dividing the machines considered into a lot of different categories, it is classed as a fighter.

machine is entirely metal covered. The more recent versions are powered with a D.B. 1,350 h.p. liquid-cooled engine and have a three-blade variable pitch airscrew. The machine has excellent rate of climb and good performance at altitude, but these good features are counteracted by poor manœuvrability at high speeds owing to heaviness of the controls. The armament consists of either one or three fixed 20 mm. cannon, and two fixed machine guns.

[*Crown copyright reserved.*]

FIG. 3.
Front view of Me. 109F.

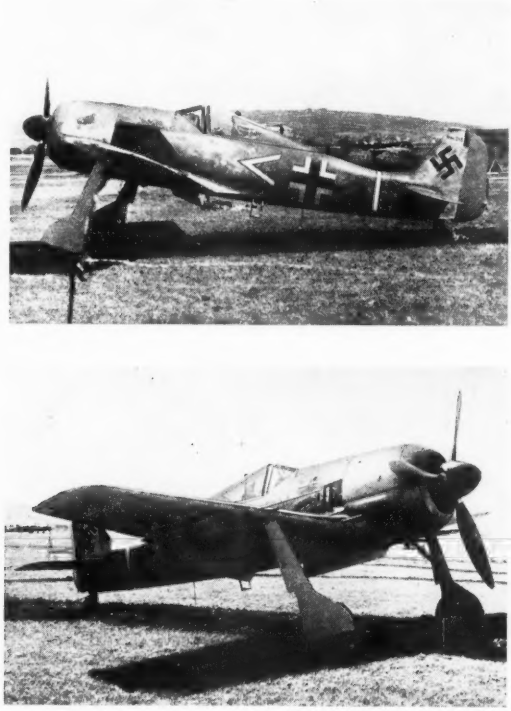


[*Crown copyright reserved.*]

FIG. 4.

The Me. 110 is a long range, low wing, twin-engined, two-seater fighter, which can also be converted to a fighter bomber or for reconnaissance. The machine is entirely metal covered except for fabric controlled surfaces. The engines are the same as in the Me. 109, *i.e.*, D.B. 1,350 h.p. liquid-cooled, and drive three-blade electrically controlled airscrews. The wing loading at about 36 lb./sq. ft. is almost the same as for the Me. 109, but the controls are lighter and not unduly heavy for a twin-engined aircraft. The armament usually consists of four machine guns mounted in the nose, two cannon in the bottom of the fuselage and one machine gun in the rear cockpit, although certain recent versions have had two extra 20 mm. cannon and an extra machine gun.

The Me. 210 and 410 are both developments of the Me. 110, and in spite of such new features as different engines, a new position for the wing joint, and a single fin and rudder, all three types have an essentially similar structure. There is, however, an outstanding difference in respect to armament, in the use of rearward firing 13 mm. guns in remote control barbettes and in the weight of armour plate carried which exceeds 900 lb. The remaining armament consists of two 20 mm. cannon and two machine guns fixed in the fuselage nose.



[*Crown copyright reserved.*]

FIG. 5.

The F.W. 190 is a small single-engined, single-seater fighter, which can also be used as a fighter bomber. It is metal covered except for the control surfaces which are fabric, and is fitted with a 1,600 h.p. B.M.W. radial engine, which gives an excellent rate of climb. The wing loading is high, 42 lb./sq. ft. in the fighter version, but in spite of this the machine is very manœuvrable and easy to handle. The armament in the fighter version consists of two machine guns above the engine, and four 20 mm. cannon, two in the wing roots synchronised to fire through the propeller and two in the wings. In the fighter bomber version only the two cannon in the wing roots are retained.

The Hs. 129 is a twin-engined, single-seater, ground attack monoplane powered by two French Gnome-Rhone radial engines of about 800 h.p. The armament normally consists of one 30 mm. and two 20 mm. cannon and two

machine guns, all of which are fixed and fire forward, but the 30 mm. cannon—when desired—can be replaced by four machine guns, or by a small bomb load. As in the Me. 210 and Me. 410, an important feature is the protection which is given to vulnerable parts of the aircraft, the amount of armour plating around the pilot's cockpit being particularly striking.

OVERALL CHARACTERISTICS OF ME. 109, ME. 110, ME. 210, ME. 410, F.W. 190, HS. 129.

Type.	Me. 109	Me. 110	Me 210	Me. 410	F.W. 190	Hs. 129
Weight (in lbs.)	6,000	15,000	21,330	22,000	8,580	12,800
Wing area (in sq. ft.)	173	414	390	390	203	305
Wing loading (lb./sq. ft.)	35	36	54·5	56	42	42
Span (in feet)	33	53	54	54	34·5	44·5
Aspect ratio	6.3	6 8	7·5	7·5	5.9	9.5
Power plant and approximate H.P.	1 × D.B. 1,350 at 18,700ft.	2 × D.B. 1,350 at 18,700ft.	2 × D.B. 1,330 at 14,000ft.	2 × D.B. 1,720 at 18,500ft.	1 × B.M.W. 1,600	2 × G.R. 800
Typical armament	1 or 3 × 20mm. 2 m.g.	2 or 4 × 20mm. 5 or 6 m.g.	2 × 20mm. 2 × 13mm. 2 m.g.	2 × 20mm. 2 × 13mm. 2 m.g.	4 × 20mm. 2 m.g.	1 × 30mm. 2 × 20mm. 2 m.g.

Coming now to the particular aspect of German aircraft, which is the subject of this paper, their structure, a brief study shows that the Me. types have much in common and can be grouped together. The next four sections are accordingly devoted to considering Me. fighter design and the design of the F.W. 190 and the Hs. 129.

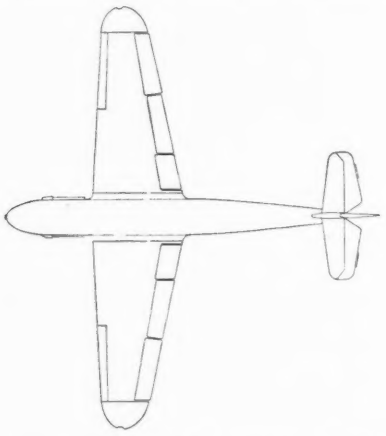
2.2. *Wing design.*

2.21. *Me.* 109, 110, 210, 410.—All four of these types have the following characteristics in common:—

(i) A single built up spar set well back at 40 to 45 per cent. of the chord.

(ii) A relatively thin skin, heavily reinforced in both spanwise and chordwise directions.

(iii) Unusual wing joints, specially designed for ease of assembly.



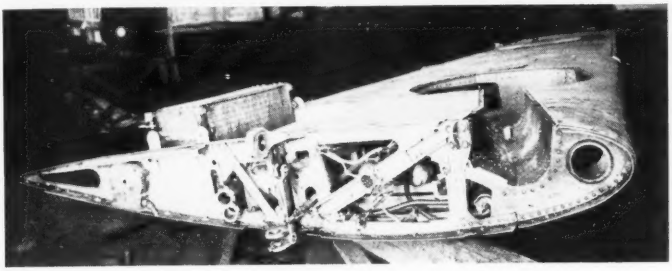
[*Crown copyright reserved.*]

FIG. 6.

Outline of Me. 109.

With regard to (i), the spar in the Me. 109 is typical and consists of upper and lower flanges and a 12 gauge plate web reinforced with angle section verticals. At the root the flanges are built up of two $\frac{1}{4}$ in. thick angles and two $\frac{1}{4}$ in. thick cover plates. Proceeding outboard the flange area decreases: first the cover plates are removed, next the front angle is omitted and its place taken by the bent over edge of the web itself, and finally the rear angle disappears.

Coming to (ii), it is felt that although the exact method of reinforcing the wing cover is slightly different in the different types, a description of the method used on the Me. 109 and 110 will give a good idea of this aspect of Messerschmitt design.



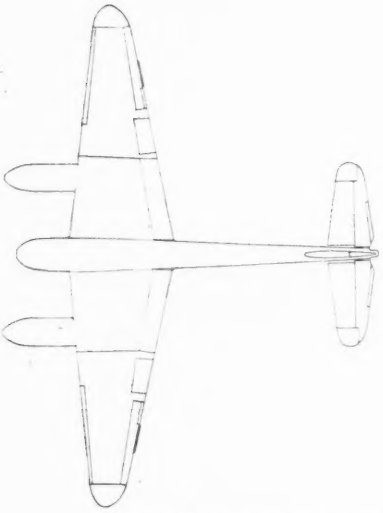
[*Crown copyright reserved.*]

FIG. 7.
Wing root joint of Me. 109.

In the Me. 109, the skin varies between 17 and 22 gauge, and so when judged by our standards is thin. It is, however, very well supported. In the chordwise direction it is reinforced by the ribs and intermediate stiffeners, and in the spanwise direction there are stringers. As the ribs are close and, except in the neighbourhood of the undercarriage cut out, at only 9 in. pitch, this means that there is chordwise reinforcement every $4\frac{1}{2}$ in. The stringers number only six, three on the top surface and three on the bottom, but they are heavy, being of 16 to 20 gauge. Both the stringers and chordwise stiffeners are of top hat section and are riveted to the skin through the crown of the hat. At points where the ribs and stringers intersect, the ribs are shaped to pass over the stringers, but at points where the stringers intersect the stiffeners, the stiffeners are broken. The ribs are of light lattice construction, with the exception of those which have some special function to perform, such as redistributing the load on either side of the undercarriage, and these are naturally heavier.

In the Me. 110, being twin-engined, it is convenient to consider the inner and outer wing separately. The inner wing, *i.e.*, the part of the wing lying inboard of the engine nacelle, contains self-sealing fuel tanks and is therefore devoid of ribs. To make up for this, however, the surface is well reinforced with stringers and chordwise stiffeners at about 6 in. pitch and of inverted top hat section. When a stringer and a stiffener intersect, the stringer is cut, but its ends are joined by a strip which is riveted to the stiffener and to the two ends of the stringer. In the outer wing, the cover is heavily reinforced by ribs of light lattice construction every 18 inches, by Z-section stiffeners and by small stringers of top hat section.

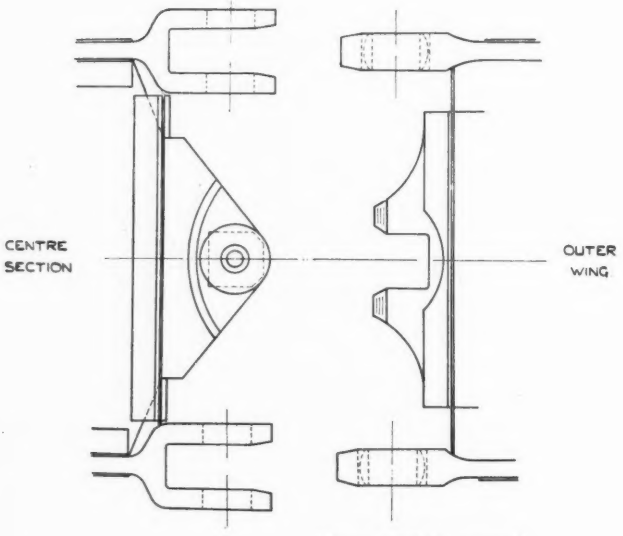
Coming now to the third outstanding feature of Messerschmitt wing design, the wing attachment joints, a description of the joints in the Me. 109 and Me. 210 will give a good idea of the methods employed. In the Me. 109 the wing is secured to the fuselage by pin joints at three points, one at each spar flange and one further forward. The bolts lie in two axes at right angles and thus permit generous assembly tolerances.



[Crown copyright reserved.]

FIG. 8.

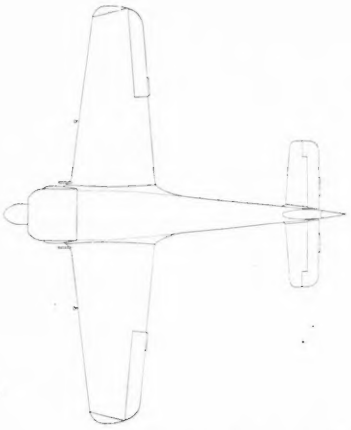
Outline of Mc. 210.



[Crown copyright reserved.]

FIG. 9.

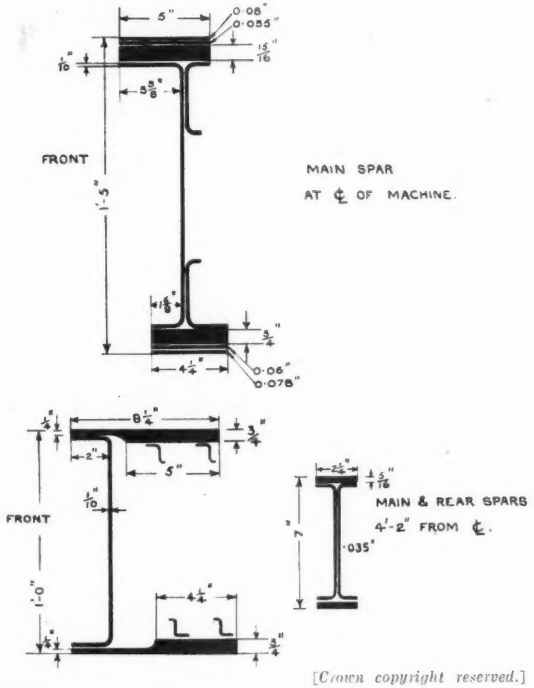
Wing joint of Mc. 210.



[Crown copyright reserved.]

FIG. 10.

Outline of F.W. 190.



[Crown copyright reserved.]

FIG. 11.

Spar section of F.W. 190.

In the Me. 210 the wing joint is outboard of the engine nacelle and a special feature is the main spar joint connecting the outer and centre sections of the wing. In this, a block which is situated on the web of the inner wing spar slides into a recess in the web of the outer wing spar, and thus ensures that no shear is taken by the flange joints. The forward attachment is a ball joint of the type used by Junkers.

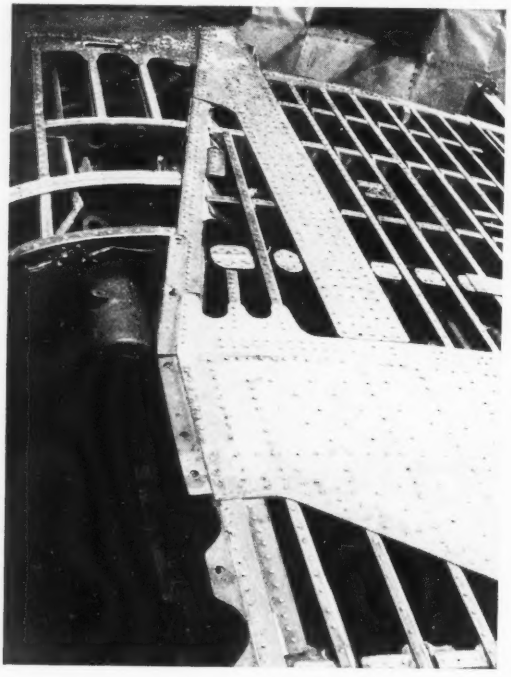
2.22. *F.W.* 190.—As the wing design of the F.W. 190 is unusual in a variety of ways it is described in some detail. The following features are, however, of particular interest:—

(i) The built up spar whose flanges fork and taper to nothing at about one-third the length of the wing.

(ii) On both surfaces the relatively thick skin covering which is reinforced in the spanwise direction by stringers at very close pitch.

(iii) The method adopted for reinforcing holes by riveting together two and sometimes three separate plates.

(iv) The method of rib construction which enables the wing to be built in two halves for ease of assembly.



[*Crown copyright reserved.*]

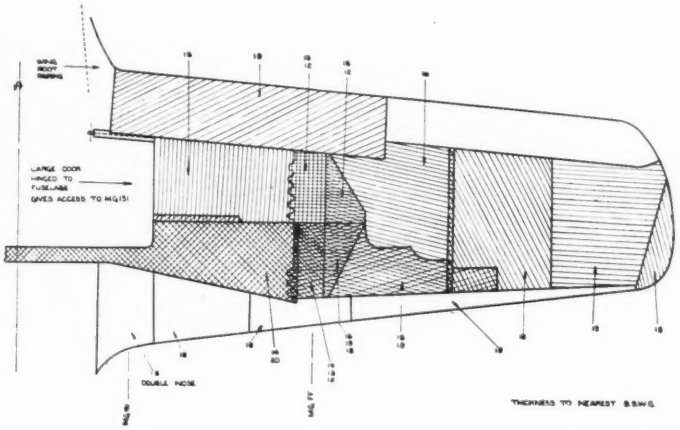
FIG. 12.

Photograph of spar of F.W. 190.

The inner portion of the wing is constructed around the main spar which is situated at 30 per cent. of the chord and is continuous right through the fuselage, and a much lighter trailing edge member which is broken at the root. Throughout the centre portion the main spar is substantial and consists of a built up I-beam

with a continuous web. The flanges consist of a pair of angles placed back to back and riveted through the web, reinforced by doubling plates. These are riveted to the outside of each pair of flanges, and at the centre line of the aircraft are 1 in. thick. To a distance of 5 ft. on either side of the centre line, the thickness of these plates remains sensibly constant, but proceeding outboard they rapidly taper to nothing. The trailing edge member is of similar construction to the main spar, but is not continuous through the centre portion. The web and flange angles are lighter, and the doubling plates are only $\frac{1}{8}$ in. thick at a point 2 ft. from the root, and taper to nothing in both directions.

At a point on the main spar 1 ft. 8 in. from the centre line, the lower flange forks, and at a point 2 ft. 9 in. from the centre line the upper flange does also. Both forward branches, however, rapidly taper to nothing. The web moves forward a total distance of 2 ft. so as to follow the direction of the forward branches of the flanges, and when these disappear it continues as a plain channel. No web connects the rear flange branches which die away to nothing at about one-third the length of the wing.



[*Crown copyright reserved.*]

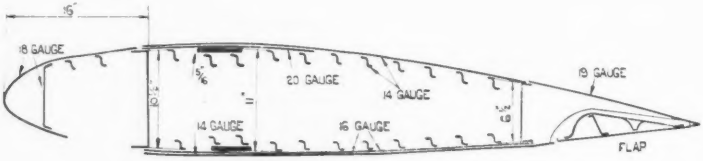
FIG. 13.

Skin thicknesses on upper surface of F.W. 190 wing.

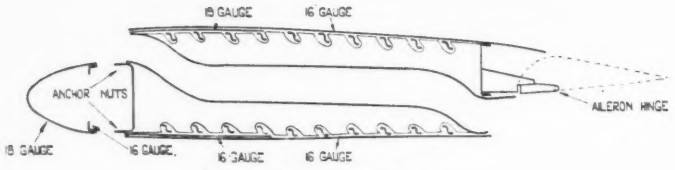
The wings are attached to the fuselage at five points, three on the main spar, and two on the trailing edge member. The main spar upper flange is connected by bolts to the lower corners of the front fuselage frame, the main spar lower flange is braced to the fuselage by a strut, and the trailing edge member of each wing is attached to the fuselage by a horizontal pin.

At the root, the bending moment is taken entirely by the main spar, but in the outer two-thirds of the wing there is no true spar, and so all direct loads are carried by the skin and stringers. The skin thickness varies considerably at different parts of the wing surface, but in general is heavy when compared with British practice, being 14 gauge at the root and 18 gauge at the tip. In this connection a feature of interest is the manner in which the wing covering is made up of two or three plates riveted together, a good example occurring in the neighbourhood of the machine gun door, where the surface consists of three 16 gauge plates. On both upper and lower surfaces the skin is strongly reinforced in the spanwise direction with rolled Z-section stringers which are 1 in. deep, at $3\frac{1}{2}$ in. pitch and vary in thickness between 14 and 17 gauge.

Coming now to the ribs and chordwise reinforcement, a remarkable feature is that in each wing all except five of the ribs are divided, each lower half reaching full depth at the front web, and each upper half at the rear web, so that the whole wing can be regarded as a combination of two shells. The upper shell consists of the upper skin and stringers, upper half ribs, the trailing edge member, and the upper flange cover plates for the centre section spar. The lower shell consists of the lower skin and stringers, lower half ribs, individual ribs, the centre section spar except for its upper flange cover plates, and the root sections of the leading edge. In bringing these two shells together to produce the complete wing, the only riveting required is through the lower flange of the trailing edge member, the upper flanges of the leading edge member, the centre section spar and the five complete ribs. The upper flanges of two of these ribs are accessible from outside, while the remainder can be reached through the doors in the lower skin which give access to the guns, and flap and undercarriage mechanisms. After joining the two shells together the leading edge and wing tips are then attached by screws driven from outside into adjustable anchor nuts.



FW 190 WING SECTION AT RIB 5.



FW.190. WING SECTION AT RIB 10

[Crown copyright reserved.]

FIG. 14.

Method of wing construction on F.W. 190.

The advantage of this arrangement is that the very large amount of riveting necessitated by the very small stiffener pitch can be done on each half shell separately, and no blind riveting is required in assembly. The undivided ribs consist of channels placed back to back, and the remainder are divided pressings; in every case the ribs are cut away so as to enable the stringers to pass through unbroken.

2.23. *Hs.* 129.—The Hs. 129 is an outstanding example of what can be done to obtain ease of production and assembly. The wings are of extremely simple design, each being made up of an outer wing, detachable just outboard of the nacelle from the inner wing, which is integral with the centre portion of the fuselage. The two spars are of identical form in both the inner and outer wings, and consist of a solid plate web stiffened on one side in an unusual manner. The stiffeners are in sets of six, and both these and the strips which connect their ends are formed by pressing a suitably cut away sheet. This gives flanged connecting strips and stiffeners of shallow top hat section (Fig. 15). Strength is

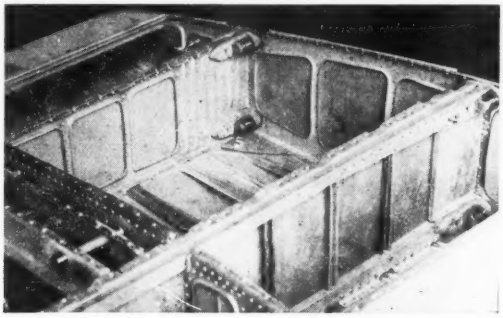
given to the spar flanges by solid rectangular section light alloy bars, tapering towards the wing tip, riveted directly on to the side of the web.

The ribs are few in number and are constructed in a similar manner to the spars, except that the rectangular section bars are not present.

The chordwise stiffeners are formed in sets in the same way as the spar and rib stiffeners, but in the pressing process are given a greater depth at the centre of each unsupported portion than, for instance, at the points where they pass over the spars.

The whole of the lower surface of an outer wing and most of the lower surface of an inner wing consist of screwed on panels, with the same type of chordwise stiffening, so that manufacture can be completed before the wing is closed up.

The outer wing is attached to the inner wing by sets of light alloy forgings of ⊓ form which lie with their legs on each side of the spar flanges to which they are bolted. The cross piece carries two tension bolts which take the bending loads and between them, in a hemispherical recess, is a steel ball for transmitting shear loads.



[*Crown copyright reserved.*]

FIG. 15.

Stiffeners on spar and ribs of Hs. 129.

2.3. *Fuselage design.*

2.31. *Me.* 109, 110, 210, 410.—The following features are common to all four Messerschmitt types, and for convenience will be illustrated in relation to the Me. 109 and 110.

(i) A fuselage of oval section except where the bottom is flattened to coincide with the lower wing surface.

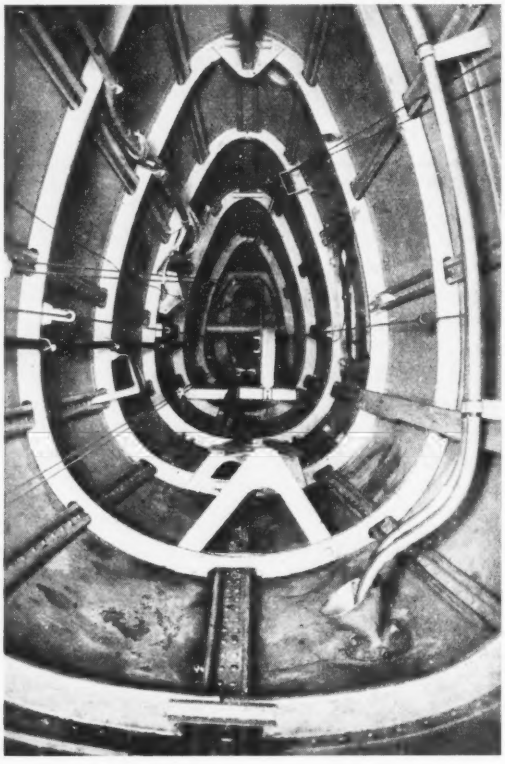
(ii) A centre section spar which is mainly of steel.

(iii) A rear fuselage specially designed for ease of production.

As there is nothing to amplify with reference to (i), we pass directly to (ii). In the Me. 109, the centre section spar is a strong girder with a continuous light alloy web and steel T section flanges, having at their ends the fittings for attachment of the wing spars. Braced to the flanges by tubular struts are two large cast steel fittings, to which are connected the forward wing attachment lugs, the lower engine mounting attachments, and the main undercarriage legs. In the Me. 110, the centre section spar has a top boom which is a 3 in. diameter steel tube, and a heavy bottom boom of T section. In place of the continuous web of the Me. 109, there is V-bracing which consists of two tubes stretching from the centre of the bottom boom to the ends of the top boom.

Coming now to the fuselage proper, there is little of interest in the front portion, which consists for the most part of a thick skin heavily reinforced by

longerons and stringers; but the rear portion contains several striking features which will be illustrated from the Me. 109. The structure is pure monocoque and is made up of two halves joined together along the plane of symmetry. In the longitudinal direction the skin is reinforced by hat section stringers, reducing in number from twelve just aft of the cockpit to six at the extreme rear end. Except for the two in the plane of symmetry these are riveted with the crown of the hat adjacent to the skin. The exceptions are of very wide section, and the two halves of fuselage are riveted to them to form butt joints. There are no separate formers, but instead, the two transverse edges of alternate sheets of



[*Crown copyright reserved.*]

FIG. 16.

Photograph of rear fuselage construction on Me. 109.

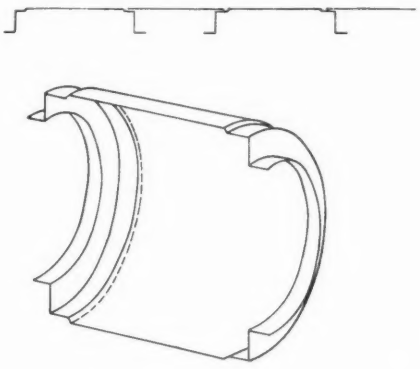
the skin covering are bent up so as to form Z-section flanges on the inside of the fuselage. The sheets are further joggled to make flush skin laps, and corresponding flanges in the two halves of the fuselage are joined by gusset plates (Fig. 17). The skin and formers are thin, being only 24 gauge, and at points where they intersect, holes are cut in the formers to enable the stringers to pass through unbroken.

2.32. *F.W.* 190.—In the description that follows special points of interest are:—

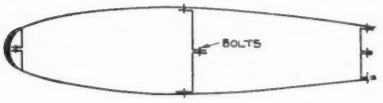
(i) The construction of the removable panel which gives access to the fuel tanks at the bottom of the fuselage.

(ii) The large number of stringers in the rear fuselage.

The front fuselage is divided at the level of the top of the main wing spar by a horizontal deck which separates the pilot's cockpit from the tank bay below. At the front of the cockpit section there is a bulkhead, to the corners of which are welded four steel fittings. Of these, the lower pair is bolted to the upper boom of the spar and constitutes the middle engine mounting attachment, while the upper pair forms the upper engine mounting attachment. To these steel corner fittings are also riveted the forward ends of the four longerons which extend backwards to the rear of the cockpit. The dividing deck is supported on three frames and on the partition between the front and rear tanks. The tanks themselves are internally stiffened fibre shells with a self-sealing covering. Access to them is by means of a removable panel of dimpled double skin, which is screwed to the bulkheads and lower longerons.



• INTEGRAL FUSELAGE PANEL AND FORMERS.



TAILPLANE SECTION.

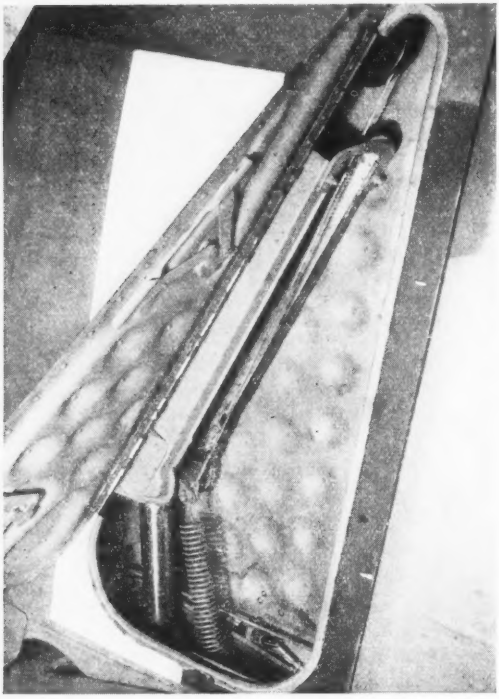
[*Crown copyright reserved.*]

FIG. 17.

Drawing showing rear fuselage and tailplane construction on Me. 109.

The rear fuselage is of conventional monocoque construction, but is remarkable in having as many as 21 stringers. These are of 16 gauge Z-section, and although the frames are cut away where the stringers intersect them, an unusual feature is the lack of any direct connection between the two.

2.33. *Hs.* 129.—The most notable feature in the construction of the Hs. 129 fuselage is the consideration which has been given from the initial stages of the design to the armament installation and to the pilot's armour protection.



[Crown copyright reserved.]

FIG. 18.

Photograph showing dimpled, double skin on F.W. 190.

[Crown copyright reserved.]

FIG. 19.

Armour plate round pilot's cockpit on Hs. 129.

The fuselage is trapezoidal in section and is made in three parts. There is nothing noteworthy in the rear fuselage, which is of conventional monocoque construction. It is connected to the centre portion by bolts passing through the two reinforced end frames. In the centre portion reinforcement of the end frame is merely by an extruded angle riveted to the frame, but in the rear portion it consists of $\overline{\Pi}$ section cast fittings. These have their legs riveted to the stringers, and the cross pieces bolted to the frame. The centre portion is integral with the inner wing and is built round two steel tubular longerons which act as blast tubes for the 20 mm. cannon. The forward ends are flanged, and the connection between these flanges and the corresponding flanges in the front portion constitutes the main attachment between the two parts.

The front fuselage contains the pilot's cockpit and is constructed almost entirely of armour plate, so that except for the armour glass windscreen and plastic transparencies, the pilot is entirely surrounded by a welded armour plate box (Fig. 19).

2.4. *Tailplane design.*

2.41. *Me.* 109, 110, 210, 410.—The following features are worth noting:—

(i) A tailplane whose incidence is variable in flight (except in the Me. 210 and 410).

(ii) A tailplane which for ease of production is constructed in two halves.

In the Me. 110, the tailplane is mounted at the top of the fuselage and pivoted about a point just below the main tailplane spar. The forward point of support can be made to move vertically by means of a screw jack, and is, in fact, interconnected with the flaps in such a way that the tailplane incidence automatically increases as the flaps are lowered.

The construction of the tailplane is unusual in that it is made in two halves, with the leading and trailing edge members as well as the main spar and ribs all split along the chordal plane (Fig. 17). When it is assembled the two halves of the spar and ribs are joined by bolts inserted through holes in the outer skin. These holes are subsequently covered by fabric and the leading and trailing edge members, being still accessible, are then joined by rivets. The assembly is completed at the leading edge by a half round section secured by screws.

2.42. *F.W.* 190.—The tailplane is continuous through the fuselage and is composed of spars, and pressed ribs with bent over flanges to which the skin is attached by riveting. As in the Me. 110, the incidence of the tailplane can be varied in flight by means of an electrically operated screw jack.

2.43. *Hs.* 129.—The design of the tailplane and fin is almost identical with that of the outer wings and the method of attachment to the fuselage is very similar.

2.5. *Miscellaneous design features.*

Among the fighters to which reference has been made there are a number of miscellaneous design features which have not so far been mentioned and which merit attention.

2.51. *Attachment of wing root fillets on Me. 109F.*—The fillets are each made in one piece, and split at the trailing edge so that they can be slipped over the wing. Metal loops are riveted to the inside of the fillet at intervals of about a foot, and through these loops is passed a strong cable. To attach the fillet, the cable is looped over a number of bobbins fixed to the side of the fuselage, and a tautening device, which is accessible through a door in the wing, then draws it tight.

2.52. *Tail wheel retraction on the F.W. 190.*—The top of the oleo piston is fitted with a crosshead carrying two pairs of rollers which slide in a pair of vertical channels housed inside the fin. The cross head is so shaped that in its

lowest position it can be turned over by a coil spring and is unable to slide up the channels. A cable passing over a series of pulleys connects the crosshead to one of the links in the starboard main undercarriage, and when this cable is pulled, the crosshead is rolled over into line with the vertical channels and drawn up by them. When the cable tension is relaxed, a spring, assisted by the weight of the tail wheel assembly, pulls the rollers down the channels where they automatically lock in the lowest position.

2.53. *Sliding hood of F.W.* 190.—This is constructed from a single sheet of moulded flexiglass and provides a rearward view which is excellent and only restricted by the pilot's head armour which is attached to the hood. The front corners of the hood are fitted with rollers which run in guides at the top edges of the cockpit, and the rear attachment is a rod sliding inside a tube attached to the fuselage. Emergency jettisoning of the hood is by means of a cartridge which is contained in the forward end of the tube, and which when ignited blows the rod out of the tube and the hood with it. At the same time the rack and pinion which normally operate the hood are disengaged.

2.54. *Fabric attachment on F.W.* 190 *control surfaces.*—The method adopted is not only easy to carry out in the first instance, but also makes stripping the control surfaces for inspection very simple.

The structural members of the control surfaces are all formed from dural sheet. A shallow channel is pressed into the flange of each member and the bottom of the channel is pierced with holes at 2 in. intervals. The fabric is laid over the relevant member and on top of the fabric is placed a steel wire. This is pressed down into the channel with the fabric underneath it, and is passed in and out through the fabric and holes. On the inside of the flange a special tool is used to force the wire into loops of such a size and shape that the wire can be stripped out easily in one direction, but will take a high load without slipping in the other. The wire is covered over by a doped fabric strip. To remove the fabric, it is merely necessary to tear off the doped strip and then to pull on the wire from the appropriate direction. Usually the loops are so shaped that the wire can be stripped out by holding the aft end of the wire, and then pulling in the forward direction.

3. Bomber Design, Do. 217 and Ju. 88.

Overall Characteristics of Do. 217, Ju. 88, Ju. 188.

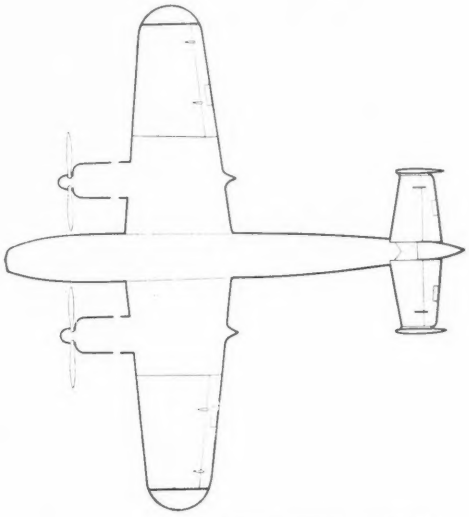
Type	Do. 217	Ju. 88	Ju. 188
Weight (in lb.) ...	34,000	24,000	—
Wing area (in sq. feet)	610	580	600
Wing loading (lb. per sq. ft.)	56	41.5	—
Span (in feet)	62	66	72.5
Aspect ratio	6.3	7.5	8.8
Power plant and approximate h.p.	2 × B.M.W. 1,500	2 × Ju. Jumo 1,200	2 × B.M.W. 1,500
Typical armament ...	2 × 13 mm. 4 m.g.	5 m.g.	1 × 20 mm. 2 × 13 mm. 2 m.g.

3.1. *General description of Do.* 217.

The Do. 217 is a twin engine, high wing, medium bomber and general reconnaissance aircraft which carries a crew of four. These comprise the pilot, bomb aimer, top rear gunner-radio operator, and bottom rear gunner, and all four are situated in a cabin which lies forward of the leading edge of the wing. The machine is entirely metal covered and is powered by two B.M.W. 14-cylinder

radial engines which are mounted in nacelles underslung from the wing. The structure is divided into several main assemblies, which for ease of production and maintenance are built up as separate units and are interchangeable with their counterparts.

3.11. *Main wing and fuselage centre section.*—The main wing and fuselage centre section is built up round two N-girder spars (Fig. 21). The flanges are T-section extrusions which taper slightly towards the tip, and are braced by vertical and diagonal members of T-section. In the centre section there is in addition a thin sheet web. The main ribs consist of T-section extrusions shaped to the wing profile, and sheet webs stiffened by vertical channels and angles. Between the spars in the fuselage centre section, there is the main fuel tank in the upper portion, while the lower portion comprises the forward part of the bomb bay. There are three self-sealing tanks in each wing—a large fuel tank between the fuselage and the engine nacelle, an oil tank between the nacelle and the wing joint and a small fuel tank in the outer wing. Large removable rectangular panels give access to these tanks from the underside of the wing. They are secured by bolts and are reinforced by Z-section stiffeners. The wing surface is flush riveted, with the joints carefully joggled to procure a smooth finish.



[*Crown copyright reserved.*]

FIG. 20.

Outline of Do. 217.

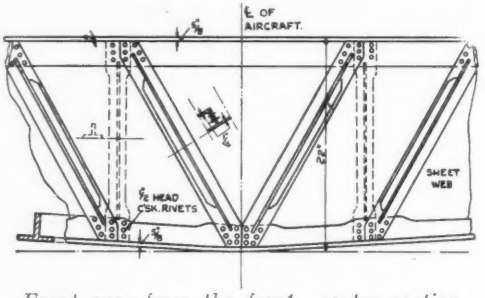
3.12. *Outer wing.*—The outer wing is joined to the inner wing by eight bolts, two at the bottom flange and two at the top flange of each spar, and by a number of small bolts distributed round the periphery.

The outer wing is similar in construction to the main wing. The spars are of the same built up type having extruded T-section flanges with girder bracing, and the ribs are sheet metal pressings with triangular flanged lightening holes. There are no stringers, but between each pair of ribs are two chordwise $2\frac{1}{4}$ in. deep Z-section stiffeners.

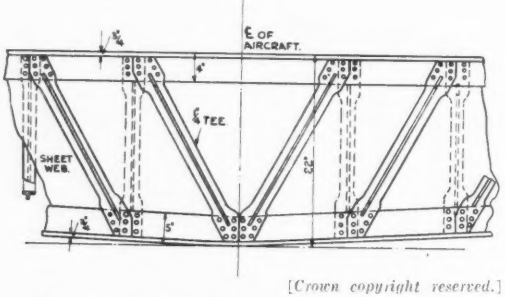
3.13. *Fuselage.*—The fuselage is built in three sections. The front fuselage contains the crew's compartment and is not remarkable in any way. The metal

skin is stiffened by Z-section frames and T-section longitudinal stringers which are discontinuous at the frames. The centre fuselage is integral with the centre section of the wing and contains the main fuel tank and the front portion of the bomb bay. The edges of the bomb openings are reinforced by box section longerons built up from angles and sheet.

The rear fuselage is approximately circular and is attached to the centre section by a number of bolts. The forward portion contains the rear part of the bomb bay and is divided horizontally by a deck. The bomb carriers are attached to the underside of this deck, and equipment which is not accessible to the crew in flight, is stored above it. Above the bomb bay the skin is riveted to $2\frac{3}{4}$ in. deep Z-section frames cut away to allow the passage of the longitudinal stringers. The rear portion, behind the bomb bay, consists of thin sheet covering with numerous stringers, and frames at about 20 in. pitch.



Front spar from the front—centre section.



[*Crown copyright reserved.*]

Rear spar from the back—centre section.

FIG. 21.

Centre section spar of Do. 217.

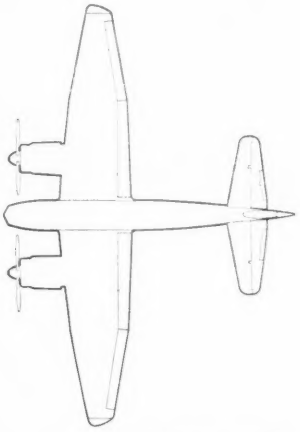
3.2. *General description of Ju. 88.*

The Ju. 88 is a twin engine, low wing, medium bomber or dive bomber, and as in the Do. 217, the crew of four are all situated in a cabin forward of the front spar. The machine is metal covered apart from fabric control surfaces, and is powered by two Junkers Jumo 1,200 h.p. engines.

The Ju. 188 is a recent development of the Ju. 88, and although the plan form of the wings is changed and the front fuselage considerably altered, including the addition of a dorsal turret, structurally the two machines are very similar. An interesting feature of the Ju. 188 is the use of steel sheet on the leading edge of the tailplane and on part of the fuselage decking, the object in the latter case presumably being to withstand the blast from the 13 mm. gun in the dorsal turret.

3.21. *Wing design.*—In the Ju. 88 the wing is constructed around two heavy spars and a light trailing edge member. The spars are built up I-section beams situated at 23 and 64 per cent. of the chord, and have heavy T-section flanges. These taper in width from 4 in. at the root to $1\frac{1}{2}$ in. at the tip, and where necessary are strengthened by the addition of angles and reinforcing flange plates. The webs of these two spars consist of $\frac{1}{16}$ in. thick plate stiffened by closely spaced verticals of top hat section.

The trailing edge member is at about 75 per cent. of the chord and consists of a web with bent over edges riveted to the skin. The skin cover varies in thickness from 0.054 in. at the root to 0.040 in. at the tip on the lower surface, and from 0.044 in. at the root to 0.026 in. at the tip on the upper surface; and is heavily reinforced by numerous chordwise stiffeners. These are of 24 gauge, $1\frac{1}{4}$ in. deep hat section, spaced 5 inches apart, and are riveted with the brim of the hat adjacent to the skin. In this connection a point of special interest, which seems structurally inefficient, is that these stiffeners are not interrupted



[*Crown copyright reserved.*]

FIG. 22.

Outline of Ju. 88.

at the spar booms but pass outside them, so that throughout its length the spar is some 2 in. less in depth than the wing.

In the inner wing, *i.e.*, inboard of the engine nacelle, there is no spanwise reinforcement at all, but in the outer wing, half way between the front spar and the leading edge, there are two stringers which are joined by vertical, angle section struts every 9 inches. Forward of these stringers the top hat chordwise stiffeners are replaced by a continuous sheet with chordwise corrugations.

Coming now to the ribs, it is interesting to note that although there are several partial ribs between the rear spar and the trailing edge, there are only five main ribs. Of these, one is at the root, one on either side of the engine nacelle, while the remaining two are situated between the engine nacelle and the wing tip. The rib at the root consists of a plate with angle section flanges and hat section stiffeners, while the two ribs in the outer wing consist of corrugated plates with angle section flanges between the spars, and flat plates with flanged lightening holes and hat section stiffeners outside them.

The only wing joint is at the root, where the attachment is by means of ball and socket joints at the top and bottom flanges of each spar.

3.22. *Fuselage.*—As in the Do. 217 the Ju. 88 fuselage splits up into three distinct sections. The front section contains the crew, and has a long glass perspex dome supported on a framework of magnesium alloy castings. The skin is of 20 gauge, and is stiffened by Z-section frames and two T-section longerons.

The centre section is bounded by bulkheads at the front spar and trailing edge, and contains a large self-sealing fuel tank in front and the fuselage bomb stowage behind, with an additional bulkhead in between. The bulkheads are of very thin sheet with vertical hat section stiffeners, while the skin covering is mainly of 18 gauge sheet strongly reinforced by Z-section frames, numerous hat section stringers and four T-section longerons. The square in the bottom of the fuselage formed by the front and intermediate bulkheads and the two lower longerons is detachable so as to give access to the fuel tank, and between the intermediate and rear bulkheads there is the cut out for the bomb doors. There are two pairs of these, side by side, and two bomb racks each carrying four bombs in tiers.

Throughout the remaining section of the fuselage the whole periphery contributes to its strength. The skin is thin, only 22 gauge, but is reinforced by 2 in. deep Z-section frames 16 in. apart, and hat section stringers at $3\frac{1}{2}$ in. pitch. While the large number of stringers of this shape leaves very little unsupported skin, it involves the use of at least twice the normal number of stringers and about three times the normal number of rivets.

3.23. *Ring spring shock absorber.*—The shock absorber strut is so designed that, on retraction of the undercarriage, it swings back into the engine nacelle, at the same time rotating through a right angle so that the wheels lie flat against the underside of the wing. In each strut the shock absorber consists of two columns of steel " ring springs " operating in series, one of which also acts as a recoil buffer. When the strut is compressed, the outer ring is expanded and the inner ring contracted, so that the energy to be absorbed is either stored in elastically straining the springs or dissipated in friction between the conical surfaces.

The special feature of these shock absorbers consists, of course, in the employment of steel compression rings of the solid ring type as the energy absorbing medium. In springs of this kind the material in the rings is stressed uniformly and therefore economically, and it is probable that a large proportion of the energy to be absorbed is immediately dissipated in friction between the sliding conical surfaces of the rings. It is, moreover, a shock absorber which should require little maintenance work in service and should be less susceptible to damage than most oleo-pneumatic types. It suffers however from the serious disadvantage of being heavy, and this seems the most probable reason for its abandonment in the Ju. 188 and the more recent versions of the Ju. 88. In a modified form, and with additional hydraulic damping, this type of shock absorber is however still employed in the tail wheel units of certain other aircraft, notably in the Me. 210.

4. General Design Features of German Aircraft.

4.1. *Services—Electrics v. Hydraulics.*

From the attached table it is clear that while there is no agreed opinion as to which is the better, hydraulics or electrics, individual firms are fairly consistent in their use of one or other.

In the table, E stands for electric, H for hydraulic, and M for manually operated.

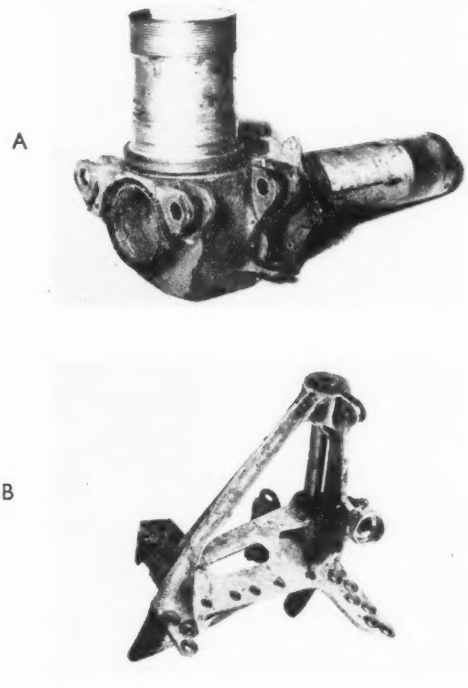
Type.	Under-carriage.	Flaps.	Dive brakes.	Tail incidence.	Bomb doors.	Turret.	Coolant radiator flaps or gills.	Oil radiator flaps.
Me. 109F ...	H	M	—	M	—	—	H	H
Me. 110 ...	H	H	—	H	—	—	H	H
Me. 210 ...	H	H	H	—	H	E	H	H
Me. 410 ...	H	H	H	—	H	E	H	H
F.W. 190 ...	E	E	—	E	—	—	—	—
Hs. 129 ...	H	H	—	—	—	—	H	H
Do. 217 ...	E	E	E	E	E	E	E	E
Ju. 88 ...	H	H	H	H	M	—	E	E
Ju. 188 ...	H	H	H	H	E	E	E	E

4.2. *Tanks.*

The petrol tanks used on German aircraft are of two main types—rigid and flexible.

The rigid tanks consist of an internally stiffened fibre shell surrounded by a self-sealing protective covering of leather (next to the fibre), soft rubber, and (on the outside) hard vulcanised rubber. In the He. 111, the tanks were placed on cradles, but in the more recent types, such as the F.W. 190, Ju. 88 and Do. 217 they are supported from underneath by webbing or thin metal straps which hold them against rubber-faced saddles attached to the top of the tank bay

Flexible tanks, which are used in all the Messerschmitt types are fully self-



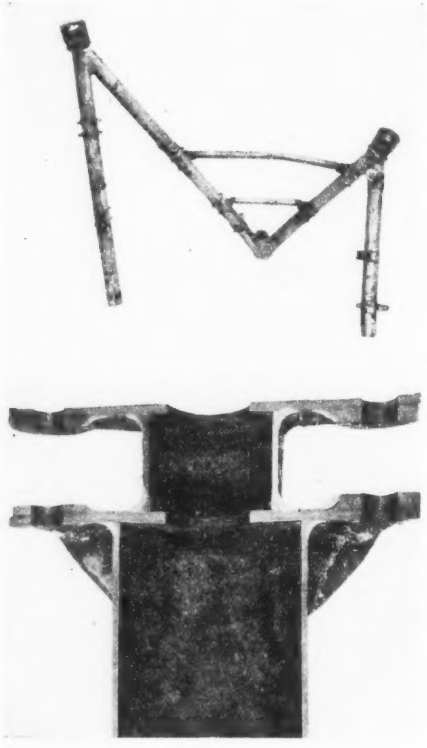
[*Crown copyright reserved.*]

FIG. 23.
Typical castings.

sealing and consist of layers of rubber and cotton fabric. They are secured at the top, and rest on a strengthened panel at the bottom of the tank compartment, where special care is taken that no projections such as bolt heads shall be allowed to chafe the tank.

4.3. *Castings and welded components.*

Considerable use is made of both castings and welded components and some typical examples are shown in Fig. 23. Fig. A illustrates the steel casting which connects the axle and shock absorber strut in the Ju. 88, and Fig. B shows one of the cast steel fittings which are attached to the two ends of the front centre section I-beam in the Me. 109. As these fittings carry the hinged lug which forms the front point of attachment for the wing unit, the



[*Crown copyright reserved.*]

FIG. 24.

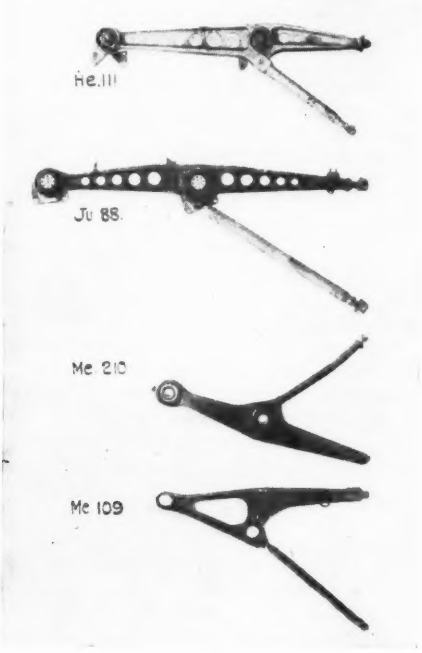
Typical welded components.

pin joint of the undercarriage strut, the down locks for the undercarriage, the engine bearer supporting strut, and a second strut which braces each of the cast fittings to the bottom of the main spar centre section, it is of special interest that such vital parts of the structure should be steel castings. Fig. 24A illustrates part of the Do. 217 engine mounting, all the joints of which are welded, and Fig. 24B shows part of the tailplane incidence adjustment crank which in the case of the Ju. 88 comprises a welded steel assembly.

4.4. *Engine mountings.*

(*a*) *Liquid cooled.*

In the majority of German types the mountings for liquid cooled engines are so similar as to be almost standard. They consist of two forged magnesium alloy bearers, which are supported in a horizontal attitude by either a tubular strut with welded-on fittings, or, as in the case of the Me. 110, by a forged light alloy strut. The bearers are attached at their rear ends to fittings at the top of the engine bulkhead by ball joints through intermediate lugs. The supporting struts are pin-jointed at their upper ends to a point about halfway along each bearer, and at their lower ends are attached by ball joints to fittings at the bottom of the engine bulkhead. There is no connection between the two sides of the engine mounting except by their mutual attachment to the engine.



[*Crown copyright reserved.*]

FIG. 25.

Typical engine mountings.

Compared with those just described, the engine mounting of the Me. 210 is an exception. For here the main bearer is attached to the bottom of the engine bulkhead and instead of being a magnesium forging it is built up from a pair of hollow light alloy stampings welded together to form a member of rectangular section.

(*b*) *Radial engine mountings.*

Of the machines considered, the only ones having radial engines are the F.W. 190 and the Do. 217, and in each case the mountings are of steel tubular welded construction. In the F.W. 190 a novel feature of the design is that the

hexagonal mounting ring which is attached to the engine at ten points is of hollow welded construction, and forms a reservoir for hydraulic fluid.

4·5. *Materials.**

In current German types about 70 to 80 per cent. of the total structure weight is aluminium, about 4 to 5 per cent. magnesium, and something under 8 per cent. steel, the remainder being accounted for by such items as rubber tyres, safety glass windscreens and fibre tanks.

4·51. *Aluminium alloys.*—Of the total amount of aluminium used, by far the largest proportion is in the form of sheet, or sections formed from sheet. The covering of the wings, fuselage and tail unit, ribs, stringers, and bulkheads, and the engine and nacelle cowlings, are always of sheet aluminium. With few exceptions the only extrusions used are the spars, and even here they often consist of a built up combination of sheet and extrusions. Thus, of the total aluminium alloy employed, about 80 per cent. is in sheet and 10 per cent. in extrusions, and the remainder in forgings and tubes.

Although recently there has been some evidence of an increase in the use of extrusions, the proportion used is still considerably less than on similar British types and constitutes a striking difference between production methods in the two countries. Of tests carried out on 18 specimens of spar material, 12 gave a proof stress in excess of 24 tons/in.^{2} and 8 gave an ultimate in excess of 35 tons/in.^{2}. The highest value was 35·6 tons/in.^{2} on the spar of an Me. 109. The high 0·1 per cent. proof and ultimate values of the German materials, coupled with their pronounced susceptibility to intercrystalline corrosion and the absence of residual strain, as shown by X-ray examination, indicate that the materials have been given an elevated temperature ageing treatment and are similar to D.T.D. 364A.

4·52. *Magnesium.*—The magnesium employed in current German types appears for the most part in forged engine bearers, in cast wheel hubs, and in tail wheel forks. It is used to some extent in undercarriage units, for example, in the main wheel fork of the Ju. 88, and also in cast form for some of the control circuit levers, and as sheet in small detachable panels.

4·53. *Steel*[2].—An investigation shows that the steels used in German aircraft are generally of high quality. In particular the highly stressed parts of the engine and most of the important structural components are made of high quality electric arc furnace steels.

As would be expected the steels show careful economy in alloying elements, especially nickel, although there does not appear to be any falling off in quality as a result. The general freedom from cracks, coupled with the difficulties in manufacture, suggest that a rigorous inspection procedure must be employed.

In general the methods of manufacture are good although they do not in all cases combine the best technique with the greatest economy in labour and material. There are no general signs of serious endeavour to economise labour by simplicity of fabrication, but the parts can be fittingly described as high special duty products made with particular attention to detail. This is especially true of the steel castings, which are clearly made under very carefully controlled conditions and probably examined radiographically.

Where welding has been used it has been found to be gas welding as the parts examined have rarely shown the use of arc or flash welding. No applications of welding to very high strength steels have been encountered, and heat treatment after welding appears to be used on only relatively small components.

The most outstanding feature of the high strength steels used in German

* Throughout this section "aluminium" means "aluminium rich alloy" containing about 94 per cent. pure aluminium, and magnesium refers to "magnesium rich alloy" containing about 90 per cent. pure magnesium.

aircraft is the very good ductility and impact values which have been obtained with the use of very small quantities of additional alloy.

4.54. *Plastics.*—The use of these is very limited, as the only plastic components found on German aircraft are such items as control pulleys, drive couplings for engine accessories, electrical and radio fittings, and occasionally aerial masts.

4.55. *Wood.*—The use of wood is almost entirely confined to propeller blades, and even these appeared in service for only a brief period during 1941 and 1942.

4.6. *Surface protection.*

German aircraft have never been protected against corrosion to the same extent as have our own, and during the course of the war the amount of protective treatment has declined still further. In the most recently constructed machines the only internal parts of the airframe which are protected are those accessible to the crew, and even then use is made only of paint. It is known that very frequent inspection and cleaning now take the place of surface protection.

4.7. *Spot welding.*

The only known examples of spot welding are in the Me. 109, where the doubling plates are spot welded to the flange angles of the spar, and in the Ju. 88, where the leading edge member is attached to the corrugated nose skin by spot welding.

4.8. *Access doors and engine cowlings.*

In the design of access doors, British and German practice differ in one important respect. For while most British types employ fairly rigid doors carefully manufactured to fit the opening for which they are designed, German practice is to make the doors flexible and then use fasteners to draw them tightly into position.

In respect to engine cowlings, there is also a difference between British and German design, for in German machines the cowling is always attached to the engine, never to other parts of the airframe, and the cowling is thus free to vibrate with the engine without risk of distortion.

4.9. *Provision for inspection and maintenance.*

German aeroplanes are always well provided with quickly detachable inspection covers in the wings and fuselage. Mention has already been made of the detachable panels which form practically the whole of the lower wing surface of the Hs. 129, and although this machine is a unique example of an aeroplane designed for ease of production and maintenance, the same is true in a lesser degree of most other German types. The F.W. 190, for example, in place of the large detachable panels, has numerous small inspection doors. A point of interest is that most of the inspection covers can be released without tools by spring-loaded push button fasteners.

In the references which have already been made to the methods of connection between some of the major components, it will have been noticed that in almost every case the methods employed are such as to ensure interchangeability and ease of assembly. The same principle also extends to engine installations which are like a " power egg," in that the engine, complete with accessories, mounting and cowling, can be removed as a single unit. The culmination of these schemes is seen in the F.W. 190, where all fuel and oil pipe connections are brought to the edges of the bulkhead and numbered, all disconnecting points are painted red and white, and the removal and replacement of an engine is then a matter for comparatively unskilled labour.

Yet another example of ease of maintenance is afforded by the self-sealing fuel tanks, for in every case all that has to be done is to remove the detachable panels below them and release the turnbuckles which fasten the webbing or metal straps which pass underneath.

5. Some General Conclusions.

5.1. *Design efficiency.*

From this standpoint, *i.e.* from the consideration of percentage structure weights, the impression given is that with the exception of the F.W. 190, recent German designs are sound without being brilliant or embodying novel forms of construction which it might be tempting to copy. This impression is, moreover, borne out by the values of percentage structure weights in the adjoining table. For although the figures given there are wholly inadequate for a generalisation, they indicate that of the three machines referred to, only the F.W. 190 has a good structure weight.

Weight Summary.

Component.	Me. 109F.	F.W. 190.	Do. 217.
Wings	12.4	13.0	13.6
Fuselage	12.3	6.1	8.3
Tail unit	1.3	1.7	1.8
Main undercarriage	4.0	5.6	5.4
Tail wheel unit	0.4	0.4	0.4
Controls	1.2	1.2	1.8
Engine mounting and cowling ...	2.4	2.9	2.7
Total structure	34.0	30.9	34.0

In this Table all weights are expressed as percentage of the all-up weight.

As regards the use of skin and stiffeners, there is no doubt that most German types employ a larger number of stiffeners, both in the wings and the fuselage, than we do, but as regards skin thickness, and the distribution of load between spars on the one hand and reinforced skin on the other, practice varies widely in different firms.

In the matter of materials, there is little which is outstanding as regards either new materials or new methods of using old ones, except in respect to the employment of steel castings which are of exceptionally high standard. At the beginning of the war the almost complete absence of extrusions was a striking feature of most German types, but this was probably dictated by production rather than design considerations, and since then the proportion of extrusions used has been steadily increasing. With reference to finish, there is no doubt that this was originally very good; and although during the war there has been slight but noticeable deterioration, the finish, especially on the Messerschmitt types is still good.

5.2. *Design from standpoint of production and maintenance.*

The earlier sections of this paper have already laid stress on the great importance which is attached to this aspect of design, and it is here that the most interesting structural features of current German types are to be found.

Good examples of design for ease of production are the fuselage and tail of the Messerschmitts and the wings of the F.W. 190 and Hs. 129. As regards ease of maintenance, two outstanding illustrations are the use of large numbers of quickly detachable inspection covers, and the arrangement whereby an engine complete with accessories, mounting and cowling, can be removed as a single unit.

5·3. *Summary.*

From the structure weight standpoint the impression gained is that with the exception of the F.W. 190, German designs are sound without being brilliant or embodying novel forms of construction which it might be tempting to copy, but as regards design for ease of production and maintenance, great efforts have been made and considerable success achieved.

REFERENCES.

1. K. Junkers. Metal Aeroplane Construction. Journal Royal Aeronautical Society, Vol. 27, Sept., 1923.

2. Dr. H. Sutton. Steels in German Aircraft. Iron and Steel, Dec. 17, 1942.

DISCUSSION.

Dr. A. G. PUGSLEY (Fellow): He had one or two general comments which concerned the beginning and the end of the paper. The authors referred to the promising early history of German construction in commenting on the Junkers machine in the first part of the paper, and at the end they said that the Germans, in this war, had not shown any special degree of structural enterprise. That seemed rather strange, because looking back on the history of German structural work they had often been very successful The Germans had been among the leading contributors to structural theory during the past 50 years; they had, for example, done a great deal of work in connection with general framework theory. Here one knew something of the theoretical work of Ritter and Muller-Breslau; and more recently, Wagner had produced his shear tension yield theory, which had been a great help structurally. In view of this, it was strange that the Germans had not been able to do better with their recent aircraft structures than apparently was the case.

In fields outside aeronautics he could not at the moment think of any practical structural achievement on the part of the Germans which was outstanding, but in aeronautics he believed it was generally felt that the early German structures showed considerable ingenuity. The authors were able to refer to only two aspects of present construction which were at all reminiscent of what the Germans did in the last war, when their Zeppelin structures represented a real advancement of the structural art. In the case of the Dornier 217, it was interesting to see the manner in which the girder construction was carried out, reminding one in side view of a Zeppelin girder; and towards the end of the paper the authors referred to the relative lack of protection against corrosion, which was a notable feature in the early days of German light alloy construction.

He had no explanation to offer as to why the Germans had contributed so little to advancement on the structural side of aeronautics during this war.

Mr. N. NICHOLAS (Fellow): Referring to the detachable panels on the wings of the F.W.190, he asked what method the Germans used for fitting them, because not long ago, on the South Downs, he found a complete engine cowl in beautiful condition marked F.W., and it had apparently been blown out of the machine. What method of attachment did the Germans use with the object of preventing the detachable panels being blown out, and do these attachments increase the drag?

Mr. DAVISON: In the F.W., and, indeed, in most of the German machines, the engine cowling was fitted by means of toggle fasteners which were so designed that in the act of fastening a big tension could be exerted on the panel, drawing it into position. They were also adjustable, so that the amount of tension could be corrected.

Detachable wing and fuselage panels were secured either by screws and anchor stiff nuts or by various types of fastener, all of which were self-locking.

The drag was, of course, increased, but was kept down to a minimum by the almost flush fit of the various types of fastener.

Mr. W. TYE (Associate Fellow): He had known both authors for quite a long time and could say that when they undertook a job they did it really thoroughly.

There were one or two questions he wished to ask although, perhaps, they were trivial. He would be very interested to know if the authors thought the fork spar of the F.W. 190 had any advantages. He presumed the intention of the fork was to disperse the loads in the wing, and as it always seemed to him that such dispersion was one of the big difficulties of design, this appeared to be a step in the right direction. Dr. Leggett had not commented whether he thought this was good or bad and it would be interesting to know if he thought it was a good feature.

Another detail point was that with the engine mountings of the in-line engines there were no side supports other than the engine itself, and he wondered how the designers contrived to pass the load through from the engine to the mounting. Were there some kind of rubber bushes or was there a solid metal to metal joint?

Also, with reference to the use of steel in the Me. 110, some time ago, soon after the first of these machines had been shot down here, he had spent a happy week crawling all over this and other aeroplanes trying to find out what they were made of. For this purpose he used a magnet and a bottle of hydrochloric acid to identify the metals. One of the surprising things revealed by that rather crude process was that there was a certain amount of steel in the spars of the M.E. 110 sandwiched between the duralumin, and at the time he was not able to account for it other than to presume that the designers had decided on a certain size of spar and found it was not sufficiently strong and therefore had to reinforce it. Was there now any information to show whether there was more in it than that the designer had made a bad shot in the first instance?

A general point was that throughout the lecture, ease of maintenance had been stressed. From this he imagined that the German aircraft was easier to maintain than our own. If that were so, was any penalty paid for that greater ease of maintenance. Usually it was found that a good design point involved other snags. For instance, in surveying the American field of design, there were certain excellent features such as ease of production, smoothness of finish and so on, but these were, to some extent, counterbalanced by difficulties in maintenance. In the case of the German machines maintenance was easy, but did that bring disadvantages with it, such as bad surface finish, as compared with corresponding British and American types of aircraft?

Dr. WILLIAMS: One of the chief points arising out of the lecture was the few innovations which the Germans had introduced especially in view of some of the rather interesting theories on the structural side that had been put out by the Germans during the few years preceding the war.

With regard to the actual details of the machines, most of the individual points which had been emphasised seemed to have had their origin in the question of production, but there were one or two points of special structural interest. There was, for instance, the method the Germans had of reinforcing some of the openings in the wing by riveting together two and sometimes three separate plates. It would also be interesting to know the cause for this method of construction. It might be that the Germans held the view that when it was necessary to reinforce a weak member the most effective way of doing so was to increase the dimensions of the existing member, in this case the thickness of the plate, rather than to add something extraneous, such as a heavy edge member. Personally, he thought they were on the right lines there. There was the alternative of using a rather heavier reinforcing ring, but in that case the chances were that the stress distribution would be altered with the possible introduction of stress concentrations, whereas by doubling or trebling the plate in the immediate vicinity of the holes they were fairly certain of maintaining the original distribution while reducing the

amount of stress, and therefore they were justified in adopting the method they had. Another explanation was that by using several thicknesses of thin plates round the opening and riveting them in the thorough manner that had been adopted, a heavy damping was introduced in the hope of reducing the considerable amount of vibration which was bound to occur in the region of the gun opening. Work recently done at the R.A.E. in connection with gun blast had shown that an arrangement of three plate thicknesses riveted together, especially if the middle thickness is of ply, has very considerable vibration damping properties.

The method of building up the spar in the F.W. 190, whose flanges forked and tapered to nothing at about one-third the length of the wing, was rather daring. He would like to know what the authors thought about that, because it undoubtedly introduced very heavy shear between the two portions, because the shear load had to go from the main web into the forward flange and then pass to what really amounted to another flange. This was a heavy flat strip stabiliser in the direction normal to its surface by two flimsy dural stringers, and, as far as he could see, the only thing apart from this that prevented buckling between the ribs was the rather flimsy skin running over it.

With regard to the engine mounting, he would be pleased to hear from any production engineer present what were the relative advantages from a production standpoint of a built-up or forged beam of this sort compared with a welded tubular structure of the orthodox type.

The only other point was that he noticed the authors mentioned that the engine cowling was other solidly attached to the engine itself or to the aircraft structure. He believed in this country the cowling was sometimes attached to both engine and airframe structure, and this was often a potent cause of vibration being transmitted to the airframe. Although the authors did not mention it, he believed that all the main joints connecting the mounting to the engine frame were rubber, which would allow of a large amount of play between the engine and airframe.

Dr. LEGGETT: In reply to Dr. Pugsley and Dr. Williams on the question of lack of originality in the structure of recent German types, there was no doubt about this conclusion, which was borne out by the small number of new designs produced by the Germans during the war. Of the few new types, the F.W. 190 was far in advance of the others in originality of structural design.

As to the fork spar of the F.W. 190, the reason for it was probably as Mr. Tye suggested. With regard to the shear stresses, the skin was by no means thin, and it might well be that it was sufficiently thick to keep the shear stresses down to a reasonable amount.

The question raised by Mr. Tye—whether ease of production or ease of maintenance were accompanied by any counterbalancing disadvantages—was an interesting one. Taking the Hs. 129 by way of illustration, he did not consider that the use of spar web stiffeners produced in groups of six, was as efficient as if they had been made independently, or that in the case of the detachable panels on the wing, it would be possible to get the same exactness of finish. At the same time, he did not think that the penalty amounted to much in the case of the Hs. 129, and the same conclusion probably applied to the Me's. and the F.W. 190.

He had no useful comment to make on the use of steel between duralumin, mentioned by Mr. Tye.

As regards the reinforcement of the F.W. 190 wing in the neighbourhood of the gun door, he thought that Dr. Williams' suggested explanation was very likely right. In this connection the Ju. 188 was of interest, for aft of the dorsal gun turret there was a steel plate riveted to the fuselage, the purpose of which was presumably to lessen the effect of gun blast.

Mr. DAVISON: There was one point he would like to mention in connection with penalties paid for ease of maintenance on some of these machines. In the case of the Hs. 129, the connecting pieces running over the top and bottom of the

spar between the individual stiffeners, represented almost entirely dead weight. Moreover, there was a loss in surface finish particularly due to the very large number of screws used in such a machine as the Hs. 129 and the Ju. 88 for the attachment of panels under the wings.

In the F.W. 190, the method of reinforcing the wing skin around the holes by simply doubling or trebling the number of sheets might have been influenced by the fact that, while reinforcing the skin in the locality of the hole as efficiently as other suggested methods, it contributed at the same time to the stiffness of the wing as a whole to a greater degree than did any other method. The F.W. 190 had an exceptionally stiff wing and very good aileron control at high speeds on that account.

With regard to the use of rubber bushes, mentioned by Mr. Tye, these were used in connection with the engine mountings, and welded steel tubular construction was used for the radial engines on the F.W. 190 and the Do. 217.

A SPEAKER expressed his interest in the question of engine mounting and said that from what he had seen of German machines the mountings were cross braced by a single tube running from the bottom to a point near the rear on the other side behind the engine. That tube, however, looked as if it were an after-thought because it had a welded lug at the end.

Mr. E. PRIBRAM (Associate Fellow): He suggested that the structure of the F.W. 190 wing was probably due to the necessity of providing room for the undercarriage when retracted. Therefore the web of the front spar was carried forward, while the flange reinforcements were placed in the structurally most favourable position.

With regard to the authors' remark on the sacrifice of structural efficiency for the sake of ease of production and maintenance, he asked whether it was not a fact that the Do. 217 was both the most difficult to manufacture and structurally the least efficient?

Dr. LEGGETT: The point made by Mr. Pribram with regard to the F.W. 190 undercarriage was a very sound one, as the undercarriage certainly would not fit into the wing if the web had not come forward a matter of 2 ft.

He quite agreed with Mr. Pribram's statement that the Do. 217 was not a good design from the structural point of view. The authors would have liked to present a table showing the percentage structure weights of British and German types, but for security reasons this was not possible. The Do. 217 was not well designed for ease of production or maintenance, as in many ways its construction was peculiarly complicated.

Mr. DAVISON: He agreed that the engine mountings of the Me. 109 and 110 were braced on one side by a small cross tube, but these were the only two machines to which this applied. The F.W. 190 split ribs were not riveted together on assembly and they seemed to act only as stiffeners. It was an interesting point that due to their great depth they had to be stabilised by very small dural strips passing over the top and riveted to the wing skin on each side. There was one such strip to each half rib.

A SPEAKER asked if the authors had found anything to lead them to believe that German machines were subject to higher stresses than British aircraft, and whether the light panels used on the F.W. 190 were comparable with anything done here. There might be a moral about the skin construction. Over here in 1937 and 1938 Farnborough showed considerable enthusiasm for it, but when it came to taking out a patent for it, it was found that Junkers had actually patented it in 1913.

Dr. LEGGETT: While it was difficult to say anything definite with regard to stresses, he was under the impression that the stresses to which the Germans worked were just as high as, and might be higher than, our own.

Mr. T. HENRY TURNER (Associate): He suggested that the German use of solid forged engine mountings, instead of built-up tubular structures, was in

line with their use of drop forged backbones for motor cycles in place of our customary tubular structures. It was possible that they chose this design of engine mounting in order to facilitate access to engines with inverted cylinders.

The suggestion made by the authors that the Germans apparently designed for a short period of life was most interesting, but the fact that excessive corrosion was not apparent either contradicted the suggestion or indicated that the German materials possessed a better corrosion resistance than corresponding materials used over here—and he did not think this was the case.

As regards the German use of steel with duralumin, he wondered whether a deliberate warping of the structure with change of temperature was indicated. He concluded by saying that as the Germans have gained a monopoly of the European forestry industry it was very surprising to find their aeroplane designers had remained so tied to metal construction. Possibly this was not because modern wood and plastics were thought unsuitable but because they had so directed the whole aircraft industry to the use of metal that it was now more difficult to introduce wood and plastics than in this country, where the mass production of modern aircraft was of more recent introduction.

Mr. DAVISON: He did not think the reason for the type of engine mounting adopted could have been to provide accessibility because it was known that the German practice, for even minor engine maintenance work, was to remove the engine completely and send it to a depot for attention, meanwhile installing a new engine. In this connection, he said the engine mounting and also the electrical and hydraulic connections were all arranged for rapid removal and installation. For instance, on the F.W. 190 there were five engine mounting disconnecting points. The electrical and hydraulic connections were brought to the side of the bulkheads so that there was no feeling about for them in the dark. Further, all the connections were numbered and painted a distinctive colour, so that the replacement of engines was a matter for comparatively unskilled labour.

As to the lack of protection against corrosion, it was known that the Germans had a regular routine for very careful inspection of the aircraft at definite periods after a certain number of flying hours. The aircraft were also, at certain intervals, returned to the makers' works for a complete overhaul and inspection for corrosion, etc., and, finally, after a certain time, they were scrapped, whatever their condition might be.

Mr. W. E. PARK (Associate Fellow): Throughout the lecture the authors had emphasised that there was a great deal of discontinuity in the structure of the aircraft, and it seemed to him that with such a type of construction the possibility of secondary failure under vibration conditions must always be present. He believed that the whole history of German construction, from the Zeppelin days onwards, showed there had always been a great deal of trouble due to local failure due to quite localised vibration. Of course, it was necessary to be able to trace the complete history of a machine to form definite conclusions, and the machines inspected by the authors had been damaged before they had seen them, but he wondered whether the authors had found any evidence of this sort of thing, and whether it was the reason for no corrosive protection being used. Any protection against corrosion would make it more difficult to see where cracking began and the lack of protection linked up with Mr. Davison's statement that the Germans had a system of very careful and frequent inspection of the surfaces after varying periods of use. This was the impression he had from listening to the paper.

Dr. LEGGETT: He rather doubted the existence of discontinuities, and thought he might have given a wrong impression about the action between heavy and light members. For the short time available it was only possible to outline certain selected parts, such as wing structure, fuselage and tail, and such a treatment might easily have given the impression of discontinuity.

Mr. PARK: In connection with stabilising the covering materials, these materials were very close ribbed and there were heavy sections placed between the stabilised coverings.

Dr. LEGGETT: The chord-wise stiffeners were usually heavy, being of 14 to 16 gauge, and being ineffective in taking any end load, were purely for stiffening. As regards vibration, he hesitated to express an opinion, as the machines which the authors had inspected were mainly bits and pieces.

Mr. T. HAAS (Associate Fellow) (*communicated*): Though the lecturers mention the superiority in design of the F.W. 190 over other types described, they failed to show wherein precisely, from the structural standpoint, this superiority lies, or how it has been achieved. A detailed weight analysis, especially for the wings, would have been of great interest.

He would also like to mention two statements the lecturers made which would hardly secure universal support from engineers. The first is at the beginning of the lecture: " . . . whereas in this country quite a number of people spring to mind as having made exceptional contributions to aeronautics, in Germany one name stands out pre-eminent—that of Junkers." Have not Dornier or Rohrbach made exceptional contributions to structural design?

The second statement concerns the future. It says, in effect, that recent German designs do not embody forms of construction which it might be tempting to copy. The engine mountings for liquid-cooled engines shown are well worth copying. The same applies to the " German " cowling, attached solely to the engine. These design principles have been generally accepted all over the Continent; so universal was their use that few Continental designers are aware that these principles originated in Germany. The American professor, F. K. Teichmann, in his *Airplane Design Manual*, writes (p. 131): " The engine mount should be so constructed that the entire power plant, including the oil system, cowling and manifold, may be readily detached for replacement." As to the engine mountings, their advantage is that they permit easy access to all necessary engine parts and accessories. By transmitting the forces and moments to the engine crankcase they can be built relatively light, whereby the forged bearers have good strength properties suitable for large scale production at a low cost, without imposing weight penalties upon them.

COMMUNICATED BY THE AUTHORS.

In reply to Mr. Haas, the authors desire to make the following points:—

The criteria for the *structural* efficiency of an aeroplane are its strength, stiffness and structure weight, and possibly (depending on the definition of structural efficiency) ease of production and ease of maintenance. In the course of the lecture it was pointed out that the F.W. 190 showed up well in all these respects.

The authors would point out that knowledge on such matters as a detailed wing weight analysis, German strength specifications, and current times for production and repair, is, to say the least, limited.

The sentence quoted by Mr. Haas should not be removed from its context. The sentence preceding it starts: " In the *early days* of any branch of engineering . . . ," and most aeronautical engineers would agree that Junkers, in 1914, or even as late as 1918, had made more outstanding contributions to aeronautics than either Dornier or Rohrbach.

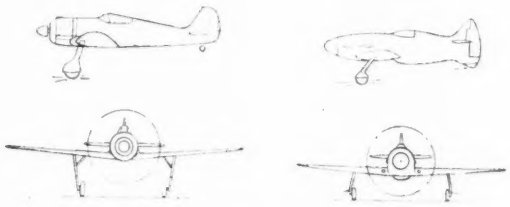
Mr. Haas has misunderstood the concluding section of the lecture, in which the more important current German types are considered from the standpoint of (i) design efficiency (defined as efficiency from a structure weight standpoint), and (ii) design from the standpoint of production and maintenance. The two good features pointed out by Mr. Haas come primarily under (ii), and not only do they both receive favourable mention in the course of the lecture, but the substance of Teichman's statement that " The engine mount should be so constructed that the entire power plant, including the air system, cowling and manifold, may be

readily detached for replacement," is emphasised in the conclusions given at the end of the lecture.

Mr. B. W. G. Foster (Associate Fellow) (*communicated*): With reference to Dr. Leggett's remarks about the Focke-Wulf 190's front spar being cranked, it is obvious that the F.W. designers were confronted with the problem of housing the long stilted undercarriage. The same problem arose when the Heston Napier Racer was built by the Heston Aircraft Co., Ltd. The wide tracked, swept forward undercarriage had to be housed in the wing when retracted, as the track was 46 per cent. of the wing span. This meant that the front spar was well forward in the wing, in fact so far forward that the Sabre engine rear feet were actually mounted on the spar. This left just enough room behind the spar to incorporate the undercarriage.

The German designers, obviously not so fortunate in having a radial engine whose compact mass kept the nose short and thus the engine farther back, were forced to crank the front spar backwards to find accommodation for the retracting undercarriage.

The enclosed sketch of these two machines to scale should be of interest, as also the following table:—



	Wing Span.		Length.		Wing Area.	Gross Wt.	Wing Loading.	Track.	
	ft.	in.	ft.	in.	sq. ft.	lbs.	lbs./ft.^{2}	ft.	in.
F.W. 190 ...	34	5	29	4	203	8580	42.26	12	0
H.N. Racer ...	32	$0\frac{1}{2}$	24	7	$167\frac{1}{2}$	7200	43.00	14	$9\frac{1}{2}$

CORRESPONDENCE.

To the Editor of the JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY.

DEAR SIR,—I have recently received the December Journal and have read with interest the translated paper "The Development of Jet or Rocket Propulsion." On page 412 the derivation is given of the formula for the maximum terminal velocity by two methods. It appears, however, that there has been an error in each of these. No doubt this has been pointed out already, but I am taking the opportunity, when forwarding my subscription, to draw this to your attention.

On line 28 the maximum terminal velocity is quoted as

$$V_{max} = c \cdot \log\left[1 - \left(\frac{m_{aa}}{m_r}\right)\right]$$

whereas this should be

$$V_{max} = c \cdot \log\left(\frac{m_{aa}}{m_r}\right)$$

On line 37 the value for "m_a" before the first explosion is shown as "m_{aa}." This should, however, be $(m_{aa} - m_r)$. The formula on line 40 then becomes

$$V = c \cdot \log\left\{\frac{m_{aa}}{(m_r + m_a)}\right\}$$

giving the corrected formula for the maximum velocity as

$$V_{max} = c \cdot \log\left(\frac{m_{aa}}{m_r}\right)$$

which agrees with that on line 28.

In view of the developments of this type of propulsion that have been recently published, I may say that I found this paper of considerable interest.

Yours faithfully,

T. W. COLERIDGE.

The Shell Company of New Zealand, Ltd.,
Wellington, N.Z.,
7th March, 1944.

REVIEWS.

HOW OUR ARMY GREW WINGS.

C. de Forest Chandler and Frank P. Lahm. Ronald Press Company, New York. 1944. $3.75.

Both Captain Chandler and General Lahm were eminently qualified to tell Americans how their army grew its wings, for both were pioneer balloon pilots and both were amongst the first American aeroplane pilots. In fact Lahm was the winner of the first Gordon Bennett balloon race and he was one of the two U.S. Army officers to be taught by the Wright brothers to fly. Lahm in his turn taught many American Army flyers and in 1933 he read the 21st Wilbur Wright Lecture before the Royal Aeronautical Society, on training the aeroplane pilots.

The inception of flying came to the United States Army from the few civilian balloonists who stimulated the U.S. Army authorities to provide personnel and

equipment for military aerostation and thus enabled the men who subsequently flew the aeroplanes, to start with the ground work of understanding the structure of the atmosphere, which as the authors very rightly say, is a matter of prime importance to all airmen.

The ballooning sportsmen having launched the army on the air, then followed up this air interest by getting their Government to buy an aeroplane, which with Orville Wright's services in 1908 and 1909 for the tests and teaching two army pilots, cost the United States the very moderate sum of £5,000.

The book describes vividly with much detail how America was slowly persuaded to buy more aircraft, and in this the general experience in America followed on similar lines to those in England, when both countries were afraid to buy because an improved design would be coming out next year and so it would be best to wait for that and not buy what would become obsolete.

As the authors say, America grew its wings in the hard way. No doubt this was so, but it was the only way, and it is only surprising that the aeroplane having originated in America, they should not have got a good start ahead of the old world. The story gives the history of struggles of the enthusiasts with the red tape of Government Departments, but brings it to the day of success on 18th July, 1914, when the Act of Congress created the Aviation Section in the Signal Corps.

The book has obviously been written for the members of the American Air Services, but it should be of interest not only to those American flyers now in Europe but to British flyers to know how America climbed to the 1914 level and how much has since been done in both America, Russia and Britain to bring the air mastery to its present pitch.

Chandler died before the book was finished, but all his records were left to General Lahm with whom he had been associated in the earlier part of the work, and now Lahm has completed his trust and produced a most authentic record of how the American Army grew its wings.

The reviewer knew Chandler at St. Louis in the first Gordon Bennett Balloon Race and can vouch for his grasp of the ballooning portion of the book and had the friendship of General Lahm for the same period and has enjoyed his hospitality at Governor's Island, New York, on many occasions up to the spring of 1941.

The book is well illustrated and is precise, impersonal and accurate. As an example af a similar history which is badly wanted, of how the English Air Force acquired similar knowledge, Chandler and Lahm's work is recommended as a reliable example.

PHYSIOLOGY IN AVIATION.

Chalmers L. Gemmill, B.S., M.D. C. C. Thomas, Springfield, Illinois. $2.00.

The material in this book was largely covered by a series of lectures on Physiology given in the School of Aviation Medicine, Naval Air Station, Pensacola, Florida.

Following short introductory and historical chapters are two on the atmosphere and gases. Chapter V deals with the mechanics of respiration and Chapter VI with alveolar air. In the following chapter the carriage of oxygen by the blood is discussed and the importance of the oxygen-hæmoglobin dissociation curve. Chapter VIII covers the carriage of carbon dioxide by the blood and in Chapter IX how chemical changes in the blood affect respiratory activity. Oxygen starvation or anoxia and its effects are covered in Chapter X. This chapter describes the general effects of lack of oxygen as well as the special effects and is followed by an important chapter on the use of oxygen in aviation, giving the ideal oxygen equipment. The chronic effects of altitude is discussed in Chapter XII, where it is pointed out that more than ten million people live

and work at altitudes of 10,000 feet and more without extra oxygen; and miners in South America live at 17,000 feet and work at 18,000 feet.

This is a most interesting and informative book.

A METALLURGICAL STUDY OF GERMAN AND ITALIAN AIRCRAFT ENGINE AND AIRFRAME PARTS.

The Aero Components Sub-Committee. Kennedy Press, London. 1944. 10/6 net.

The Aero Components Sub-Committee was formed by the Technical Advisory Committee to the Special and Alloy Steel Committee to examine the materials of enemy aircraft. It was under the chairmanship of the late Dr. W. H. Hatfield.

The Committee has made an examination of an extensive range of engine and airframe parts of German and Italian aircraft. The reports of the Committee are collated in the present work.

Very full details are given of the mechanical and chemical qualities of the materials examined, methods of manufacture, efficiency of heat treatment, or finish, and other details of use to metallurgists. The book is divided into sections covering the component parts of aircraft and aero engines and is extremely well illustrated.

All the profits from the sale of this book are being given to the Royal Air Force Benevolent Fund.

PARATROOPS.

F. O. Miksche. Faber and Faber, Ltd., London. 1943. 10/6 net.

This is the first book in the English language to consider the importance of paratroops.

Military minds are not, in the majority of cases, elastic. Imagination is not, normally, a military attribute. The history of the aeroplane, as far as its purely military use is concerned, has, until quite recently, not been very inspiring. The war offices of the world saw little in the possibilities of aviation as late as 1912, and even the war of 1914-1918 did not inspire them to forsee what is now actually happening. More often than not it is the force of events which has had to provide the necessary impetus for military authorities to do what should have been clear before the event. The course of the present war is providing that impetus in such a way that future conceptions of tactics and strategy must inevitably throw overboard many of the fixed ideas which worked comparatively well until the coming of the aeroplane.

No longer is war a problem of two dimensions. It has become one of three dimensions and that is the course of all future planning.

Captain Miksche has written one of those books which at the time of writing is highly controversial but which, in a few years' time, will be looked upon as a contribution of considerable merit to this new form of warfare. In his book he deals firstly with the development of airborne troops and their use in the Spanish Civil War and the present war up to the fall of Crete. These chapters are followed by chapters on the actual employment of airborne troops and finally the organisation for defence.

This is a book which should definitely be read by all those who are interested in air strategy and tactics. It puts forward many practical and detailed suggestions for the organisation and employment of airborne troops, and the author does not overlook the importance of other branches of military science.

"The under-rating of an arm is a dangerous thing," he comments. "The over-rating of it is no less so. No arm by itself is fully decisive. It forms only one more or less important cog in the complicated machinery of modern warfare. The secret of success lies in the purposeful combination of all the cogs, in the common march of the assembled war machine to victory."

The paratroops form an important cog in the war machine, perhaps a more important one than many people foresee.

THE TESTING OF AERO ENGINES.

R. A. Beaumont, A.F.R.Ae.S. Pitman and Sons. 1943. 7/6.

Not a great deal has been written on aero engine testing and this book will be welcome for that reason alone. It is written mainly for the use and help of ground engineers and aeronautical students. Chapter I is concerned with general considerations; Chapter II, dynamometers; Chapter III, test-house instruments and accessories; Chapter IV, tests on normally aspirated engines; Chapter V, tests on supercharged engines; and Chapter VI, testing with a calibrated airscrew or fan.

Full descriptions are given of the testing equipment and instruments, their uses, adjustments and readings, and the various tests which should be carried out to obtain the complete information about the engines under test.

The author has written a compact manual full of information of use to students and others, and the book can be well recommended.

THE BIRTH OF THE ROYAL AIR FORCE.

Air Commodore J. A. Chamier. Pitman and Sons, Ltd. 1943. 15/- net.

The official history of the Royal Air Force, from its beginnings to the end of 1918, is in six volumes. Excellent volumes they are, too, but they are not suitable for the normal reader who does not want to make a close detailed study of the Royal Air Force, but does want a connected story.

Air Commodore J. A. Chamier has provided that story, and few men are better qualified to do so. It is a pitiful and a glorious story, pitiful in its beginnings. In 1908 Colonel J. F. Seeley (now Lord Mottistone) speaking on behalf of Mr. Haldane, then Secretary of State for War, to a deputation of pioneer aircraft constructors, said: "Gentlemen, much as we would like to help you in placing orders, we regret we cannot do this as we are trustees of the public purse and we do not consider that aeroplanes will be of any possible use for war purposes."

Even following the famous Rheims meeting of 1910 high British military officers, who attended it, came away convinced there was nothing in aviation! Captain Dickson, the first British officer to fly, did so at his own expense, and was objected to by the military because his aeroplane frightened the horses.

But in February, 1911, an Army Order organised an "Air Battalion of the Royal Engineers, to which will be entrusted the duty of creating a body of expert airmen." Early that year the Admiralty permitted four naval officers to learn to fly.

In 1912 there were 19 serving pilots, against over 260 in France. Captain Murray Sueter, giving evidence before the Technical Sub-Committee of the Committee of Imperial Defence, said, among other things that he foresaw a European war with each side trying to use hordes of aeroplanes, and a war in the air would result, in which the loser would be at a hopeless disadvantage.

Out of the recommendations of this committee, whose chairman was Colonel Seeley, came the Royal Flying Corps. A little over two years later it was at war. Air Commodore Chamier's book follows the glorious story through, from the early days when air machines were fired upon by British, French and Germans alike, until the Royal Air Force became the greatest air force in the world, with a magnificent tradition built up in four short years.

In the words of the author, "In all this story a last word must lie with the men of the Flying Services. Nothing could deter them, no odds were too great, their life was often short, their spirit never flagged, and they created a tradition for the youngest of the Services which will be of inestimable value."

"The Birth of the Royal Air Force" is a book which should be read by all who owe so much to the gallantry of those who fly in war.

THE CHEMICAL BACKGROUND FOR ENGINE RESEARCH.

Edited by R. E. Burk and O. Grummit. Inter Science Publishers, Inc., New York. 1943. $3.50.

This is Volume II of the series "The Frontiers of Chemistry," published under the auspices of Western Reserve University. The university has begun an interesting experiment in the field of science and research. To keep the students in touch with any particular field as a whole the university invited distinguished scientists in the field of chemistry and closely related fields to be professors for a day and to present two lectures each.

This book is the result. Dr. Ernest F. Fiock, Senior Physicist in the Automotive Power Plants Section of the National Bureau of Standards, gives a survey of Combustion Research; Major Bernard Lewis, chief of the Explosives and Loading Division, has written the section on the Experimental Side of Combustion Research in Engines; Dr. Frank C. Whitmore, Dean of the School of Chemistry and Physics at Pennsylvania State College, that on Synthetic Methods for Hydrocarbons; Dr. Guenther van Elbe, who is on the staff of the Coal Research Laboratory of the Carnegie Institute of Technology, where he became noted for his research on thermodynamic properties of flame gases, flame velocities and kinetics of gas reactions, contributes the section on this subject; Dr. F. D. Rossini, chief of the section on Thermochemistry and Petroleum Chemistry at the National Bureau of Standards, provides the section on Chemical Thermodynamics of Hydrocarbons; and Dr. Otto Beeck, head of the Physics Department of the Steel Development Laboratories in Emeryville, California, has written the section on Some Physicochemical Aspects of Lubrication.

All sections are excellent, and not only well illustrated, but each has a useful bibliography.

This experiment of the Western Reserve University has proved very successful and is one which is worth while copying throughout all forms of teaching. Few things are more encouraging to students than to listen, as part of their lectures, to the views and experiences of those in authority in that industry and research in which fields the student ultimately desires to make his livelihood.

BASIC RADIO.

C. L. Boltz. Nelson's Aeroscience Series. Nelson and Sons, Ltd. 1943. 5/- net.

The series of Nelson's Aeroscience Manuals, under the general editorship of Professor H. Levy, has been reviewed from time to time in the Journal and its excellent qualities remarked upon.

This volume keeps up the high standard set by the earlier volumes. It is an elementary text book, but one which will lay very sure foundations for anyone first entering the field of radio, a field which is expanding at a rate, due to intense war research, which has been the most remarkable expansion of any field of science in such a comparatively short period.

The first eight chapters deal with the fundamentals of electricity, and the remaining nine on waves, valves, receivers, aerials, etc.

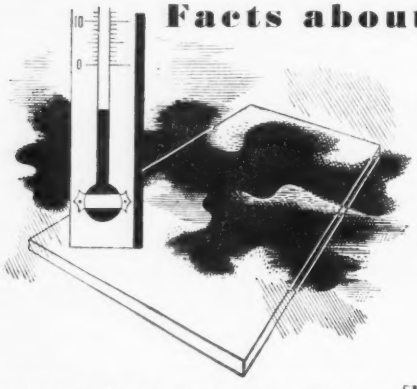
As usual in this series the explanations are not only simple, but clear, beginning with the everyday cycle battery, electric kettle and the like, familiar manifestations of electricity to all. Simple experiments are suggested for the student to verify the statements made and at the end of each chapter is a series of exercises to test the student's grasp of what he has read.

Like all the books at present published in this series, it can be unreservedly recommended.

The "FULMAR"
The Fulmar petrel is found around Britain's northern shores, and elsewhere. Of recent years its numbers have tended to increase.
Although gull-like in general appearance, its flight is distinctive.
FAIREY AIRCRAFT

IN
EVERY
SKY...
Exide
AIRCRAFT BATTERIES
THE CHLORIDE ELECTRICAL STORAGE COMPANY LTD. GROSVENOR GARDENS HOUSE, GROSVENOR GARDENS, LONDON, S.W.1 · TEL: VICTORIA 2299 'GRAMS: CHLORIDIC, SOWEST, LONDON
W.MSC 718/43

Facts about



'PERSPEX'

REGD. TRADE MARK.

ACRYLIC RESIN SHEET

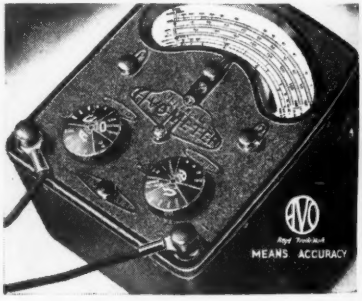
Does not become brittle at low temperatures.
Does not discolour with age.

ICI

IMPERIAL CHEMICAL INDUSTRIES LTD.

Sales Offices at: Mill Hill, London, N.W.7; Oldbury, near Birmingham; Alderley Edge, Cheshire; Bristol; York; Newcastle-on-Tyne; Leicester; Bradford; Cardiff; Sheffield; Glasgow; Belfast; Dublin.

P.140



THE MODEL 7 *50-Range Universal*

AVOMETER

Electrical Measuring Instrument

A self-contained, precision moving-coil instrument, conforming to B.S. 1st Grade accuracy requirements. Has 50 ranges, providing for measuring A.C. & D.C. volts, A.C. & D.C. amperes, resistance, capacity, audio-frequency power output and decibels. Direct readings. No external shunts or series resistances. Provided with automatic compensation for errors arising from variations in temperature, and is protected by an automatic cut-out against damage through overload.

Orders can now only be accepted which bear a Government Contract Number and Priority Rating

Sole Proprietors and Manufacturers:

AUTOMATIC COIL WINDER & ELECTRICAL EQUIPMENT CO., LTD.

Winder House, Douglas St., London, S.W.1. Tel. 3404

AIR NAVIGATORS

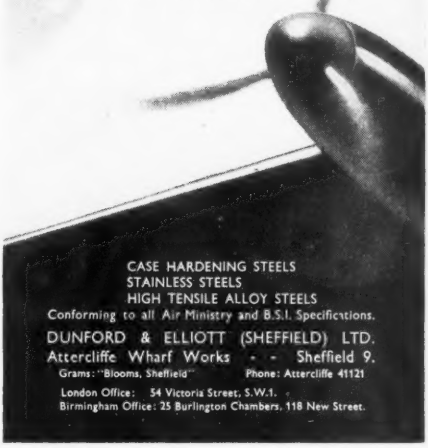
Makers of all types of Protractors for nearly thirty years, we are producing the celebrated "DOUGLAS" Protractor in ever increasing quantities. The "DOUGLAS" Protractor is indispensable to all navigators, supplied in two sizes, 5" and 10" square.

The "MACLEAN" D.R. (Dead Reckoner) Protractor of new design is now in full production. Designed primarily for Air Navigation, it is simple to use and serves as a constant reminder of essential data.

For further particulars of these two instruments and all other navigational aids, write for our illustrated brochure to

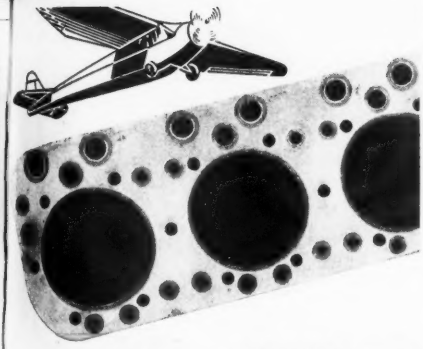
LONDON NAME PLATE
MANUFACTURING CO LTD
ZYLO WORKS BRIGHTON 7

Dunelt
Special Steels
FOR AIRCRAFT



CASE HARDENING STEELS
STAINLESS STEELS
HIGH TENSILE ALLOY STEELS
Conforming to all Air Ministry and B.S.I. Specifications.

DUNFORD & ELLIOTT (SHEFFIELD) LTD.
Attercliffe Wharf Works - - Sheffield 9.
Grams: "Blooms, Sheffield" Phone: Attercliffe 41121
London Office: 54 Victoria Street, S.W.1.
Birmingham Office: 25 Burlington Chambers, 118 New Street.



All Metal GASKETS

Corrujoint Gaskets are the choice of many leading aero-engine manufacturers. Made of a single sheet of corrosion resisting metal, with a corrugated face to ensure a perfect seal, they eliminate blowing and cracking. High temperature and pressures cannot damage Corrujoint.

Details and Quotations sent on Request.

THE CORRUGATED PACKING AND SHEET METAL CO. LTD.
GATESHEAD-ON-TYNE-ENGLAND
TELEPHONE 71785 GATESHEAD • TELEGRAMS CORRUJOINT GATESHEAD

THE ME PATENT

UNIVERSAL
BALL JOINTS

THE LIGHTEST, MOST EFFICIENT & COMPACT UNIVERSAL JOINT MANUFACTURED

Used on all types of Aircraft for engine controls, remote operation of various mechanisms, flap operating gear and undercarriages

MOLLART ENGINEERING
COMPANY LIMITED
Precision and Production Engineers
KINGSTON-BY-PASS, SURREY

Designed and produced by proved Precision Engineers with Air Ministry Gauge Test House
Ref. No. 89755/31 Tel: ELMBRIDGE 3352/3/4/5

INDEX TO ADVERTISERS

Aeroplane and Motor Aluminium Castings, Ltd. xxii
Angus, Geo., & Co., Ltd. ii
Armstrong Whitworth, Ltd. vii
Automatic Coil Winder & Electrical Equipment Co., Ltd. xx
Automotive Products, Ltd. vii

Bakelite, Ltd. ii
Birkett, T. M. & Sons, Ltd. xiv
Blackburn Aircraft, Ltd. xx
Booth, James, & Company Ltd. ... xxiii
Bristol Aeroplane Co., Ltd. ... *Back Cover*
Bunhill Publications, Ltd. xvii

Central Chemicals, Limited xviii
Chloride Electrical Storage Co., Ltd. xix
Corrugated Packing & Sheet Metal Co., Ltd. xxi

Dowty Equipment, Ltd. xiii
Dunford & Elliott, Ltd. xxi

English Steel Corporation, Ltd. ... xii

Fairey Aviation Co., Ltd. xix
Ferodo, Ltd. xii
Field Consolidated Aircraft Services, Ltd ix
Firth, Thos. & Brown, John, Ltd. ... x
Firth-Vickers Stainless Steels, Ltd. ... viii

Hawker Aircraft, Ltd. x
High Duty Alloys, Ltd. v
Hobson, H. M. (Aircraft & Motor Components), Ltd. xv
Hughes, F. A. & Co., Ltd. iv

I.C.I. Plastics xx
Lablo Propellers, Ltd. ix

Lee, Arthur & Sons xxii
Leytonstone Jig and Tool Co., Ltd. viii
Lodge Plugs, Ltd. xv
London Name Plate Co., Ltd. ... xxi

Macrome, Ltd. xxiii
Magnesium Castings & Products, Ltd. iii
Mollart Engineering Co., Ltd. ... xxi
Morrisons Eng. xii

Napier, D. & Son, Ltd. xvi
Newall, A. P. & Co. ... ... *Back Cover*

Pitmans ii

Reynolds Tube Co., Ltd. xiii
Roe, A. V. & Co., Ltd. xviii
Rolls-Royce, Ltd. v
Rotol Airscrews, Ltd. xiv
Rotax, Ltd. vi

Sangamo Weston, Ltd. xvi
Short & Mason, Ltd. x
Smith's Aircraft Instruments, Ltd. ... xi

Ultra Electric Ltd. xiv

Vickers Armstrongs, Ltd. iii
Vokes, Ltd. xviii

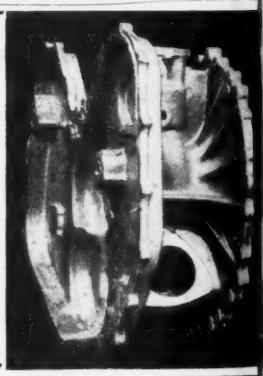
Westland Aircraft, Ltd. xv
Wickman, A. C., Ltd. iv
Wilkinson Rubber Co. vi
Warwick Aviation Co., Ltd. xi

Yorkshire Engineering Supplies, Ltd. xvii

HIGH CLASS ALUMINIUM SAND CASTING

Produced by—
AEROPLANE & MOTOR ALUMINIUM CASTINGS LTD.
WOOD LANE,
ERDINGTON,
BIRMINGHAM, 24

Suppliers of Aluminium and Magnesium Alloy Die and Sand Castings of every description.



LEE OF SHEFFIELD

AIRCRAFT STEELS

SPECIALISTS IN THE PRODUCTION OF—
Hot and Cold Rolled Steel Strip
Bright Drawn Steel Bars and Wire
Stainless Steel Bars, Strip and Wire

ARTHUR LEE & SONS, LTD.

SHEFFIELD, 9

London Office:
Mowbray House, NORFOLK ST.,
STRAND, LONDON, W.C.2
Tel. Nos.: Temple Bar 7187 & 7188

Birmingham Office:
155, CHURCH LANE,
HANDSWORTH WOOD,
BIRMINGHAM, 20
Tel. Nos.: Northern 2116 and 2117

1944

Ju

Telephone: EAST 1221.

James Booth & Company, Ltd.
Birmingham, 7

PIONEER MANUFACTURERS
IN GREAT BRITAIN OF
STRONG ALUMINIUM
AND
MAGNESIUM ALLOYS

DURALUMIN ALDURAL DURAL
REGISTERED TRADE MARK REGISTERED TRADE MARK REGISTERED TRADE MARK

M.G.7
REGD. TRADE MARK

"ELEKTRON"
REGISTERED TRADE MARK

The demand is increasing daily —

—for Macrome-brand tools and for small tools treated by the Macrome tool-toughening process, as manufacturers come to realise the outstanding advantages the Macrome-treatment of small tools offers in increased production, in reduced labour and in greater average tool performance. THREE THOUSAND of the leading engineering firms in the country now regularly use Macrome-treated tools.

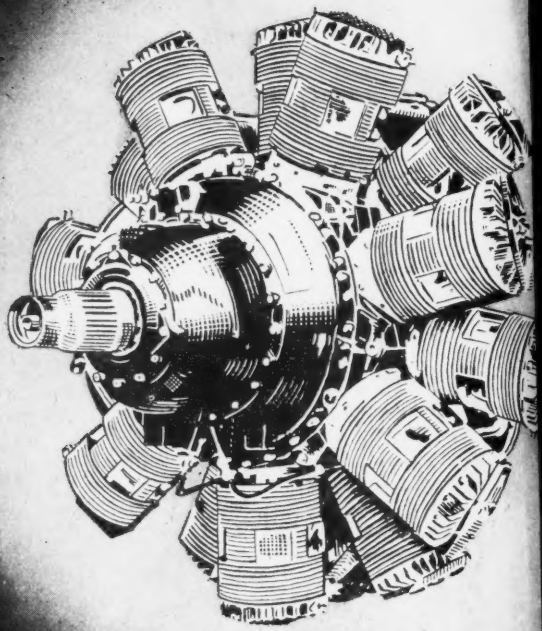
MACROME
THE TOUGHEST TOOLS
IN THE WORLD

MACROME LIMITED, ALCESTER, WARWICKSHIRE
ALSO AT LONDON · GLASGOW · MANCHESTER · LEICESTER · LEEDS
COVENTRY · BRISTOL · NEWCASTLE-ON-TYNE · BIRMINGHAM · BASINGSTOKE

Britain's Power in the Skies....

AIR-COOLED RADIAL ENGINES by

"Bristol"



THE BRISTOL AEROPLANE COMPANY LIMITED. BRISTO

Newallastic

WE have received many enquiries with regard to the physical properties of "NEWALLASTIC" bolts and studs. They have a tensile strength of 65/75 tons, with an elongation of 15% and upwards, and a reduction in area of 55/60%.

Owing to the patented process by which they are manufactured, they have a greater resistance to fatigue than any bolts or studs hitherto obtainable.

The threads are produced by an entirely new method and are almost as accurate as the finest gauges.

"NEWALLASTIC" Bolts and Studs are the last word in STRENGTH AND ACCURACY.

A. P. NEWALL and CO., LTD.
POSSILPARK. GLASGOW. N.

Printed by the Lewes Press (Wightman & Co., Ltd.), Friars Walk, Lewes, England, and Published by the Royal Aeronautical Society, 4, Hamilton Place, London, W.1, England.